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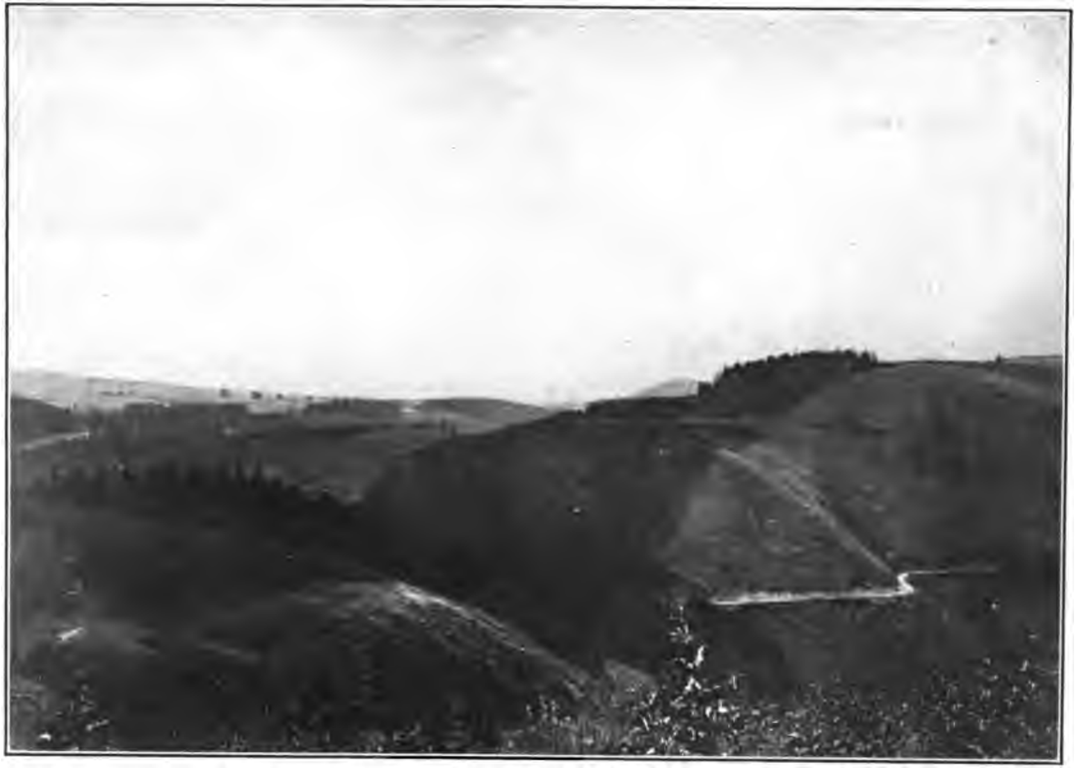

A FOREST UNDER MANAGEMENT

Norway Spruce in Saxony. Note Cutting Series and Compartments. This forest is reproduced by clear-cutting and planting. (Courtesy of Director James W. Toumey.)

FOREST MANAGEMENT

BY

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AND

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To

THE CORNELL FORESTERS

WHO

AS STUDENTS, CO-WORKERS, AND FRIENDS

HAVE BEEN AN UNFAILING SOURCE

OF INSPIRATION

401307

PREFACE

TEXTBOOKS on forestry have multiplied so rapidly in the past decade that an explanation is due the profession for adding another to an already long list.

The textbooks extant are either highly technical or else very elementary in their presentation. It seemed to the authors that there was room between these two extremes, for a condensed and simple treatment of the subjects included. Without impinging on the realm of such standard works as Graves: "Forest Mensuration," Chapman: "Forest Valuation," and others of the same class, there appears to be a real need for a treatment of these subjects, which, while comprehensive, is sufficiently condensed so as to be readily understood and used by the layman timber owner and manager. At the same time, the book should be of use to non-professional students of forestry in colleges and universities and in professional courses which are not of post-graduate grade.

Special acknowledgment is due Mr. C. H. Guise for his assistance in the chapters on Forest Organization and Forest Finance, particularly the latter. This chapter is modeled on Chapman's treatment of the subject in his "Forest Valuation," a relationship which is gladly acknowledged.

It is the earnest hope of the authors that this humble contribution to an ever-growing English literature on forestry may stimulate the practice of forest management by owners of timberland — large and small, public and private — to the end that this important natural resource may be systematically maintained and developed.

A. B. RECKNAGEL,
JOHN BENTLEY, JR.

ITHACA, NEW YORK,
November, 1918.

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INTRODUCTION

FORESTRY has been defined * as the science and art of managing forests in continuity for forest purposes. The five main branches of forestry are: Forest policy, Silviculture, Forest protection, Forest utilization, and Forest management. The last named, the subject of this book, is the practice or application of forestry in the conduct of the forest business. Forest management consists of four main parts, each of which will be taken up separately in the order named: (1) Forest mensuration, (2) Forest organization, (3) Forest finance, and (4) Forest administration.

(1) Forest mensuration deals with the determination of the volume of stands, trees, logs and other timber products, and with the study of growth and yield of trees and stands.

(2) Forest organization concerns itself with the organization of a forest property for maintenance, ordering in time and place the most advantageous use of the property, with the ultimate aim of securing a sustained yield.

(3) Forest finance relates to the forest as an investment.

(4) Forest administration deals with the principles of business conduct and methods employed in the administration of forest properties.

The Committee of the Conference of Forest Schools in 1912,† recognized that "Forest management in its broadest sense includes a group of subjects which deal with the quantitative and financial aspects of forestry, and with business considerations. Forestry as a business must conform to the principles which make for success in any other business. This means securing the high-

---

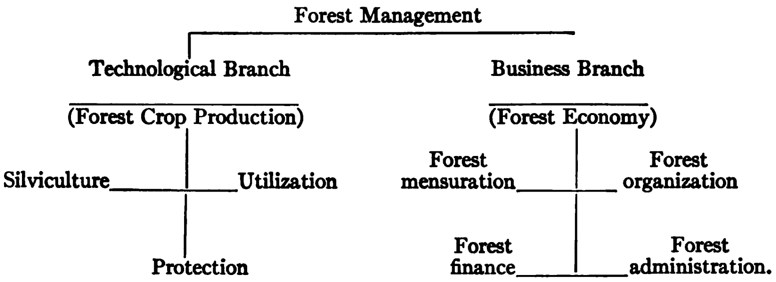
* Definitions throughout from terminology of the Society of American Foresters Journal of Forestry, Vol. XV, No. 1, pp. 71–101; reprinted 1917.

† "Standardization of Instruction in Forestry," Forestry Quarterly, Vol. X, No. 3, pp. 341–394.

est returns on the investment, the most efficient organization and conduct of operations and the regulation of the forest output so as to secure a permanent and steady income.

"While the attainment of these results is dependent on knowledge of practically all conditions which affect forests, from the academic point of view it is desirable to segregate two groups of subjects which deal, to be sure, with methods and conditions on which management must be based, but may be treated separately, namely, the technical group, including silviculture, lumbering, protection — crop production and harvest; and the economic group, including studies of forest influences, statistics, forest laws, which determine guiding principles or objects to be attained by the management. Forest management is to harmonize these abstract principles and technical methods with the financial condition of the owner, map out the exact nature and extent of the operations which can be most effectively carried out, organize the work, and secure the quantitative and financial results desired for the tract as a whole."

The term forest economy has been suggested as a collective name for the subjects which deal with business problems as separated from forest crop production, *i.e.*, forest economy would be a comprehensive term including all matter dealing with the business aspects of forest management. This can be shown diagrammatically as follows:



The logic of this classification is incontrovertible; nevertheless, the term "forest economy" has the serious drawback of tonal similarity to "forest economics." The latter is akin to politics or political economy; development of state policies with regard to natural resources. "Economy" suggests the more confined sense; household arrangement of an establishment, rules and regulation and orderly system by which an establishment is run or managed.*

The term "forest management" is simple, inclusive, and readily understood. It is the term in common usage to-day for the subjects included in this book.

---

* From letter by Dr. B. E. Fernow to one of the authors under date of December 4, 1916. See also Forestry Quarterly, Vol. III, p. 260.

UNIV. OF CALIFORNIA

FOREST MANAGEMENT

CHAPTER I

SURVEY OF AREA

1. Necessity of a Survey. — Except in the case of woodlots of very small area in which every tree can be counted and estimated, or in those rare cases where trees of unusual value are being appraised, an estimate of standing timber will be based on a general inspection of the entire tract, followed by a more or less detailed count and estimate of the trees on a fractional part of the area, which represents, as nearly as may be judged, the average of the entire stand, or type. The area of this fractional part, which may be in the form of one or more plots or strips, must be known; and the area of the entire tract or type of which the samples are a part must also be known, in order that the ratio between the two can be established; only in this way can the estimate-figures obtained be translated into terms of the entire area. The area of a piece of timber-land can sometimes be gotten quite accurately from the description in the deed referring to it, but more often it will be necessary to make a fresh survey in order to be sure of accuracy. The forest may have spread by natural reproduction beyond the limits described in an old deed; or cuttings, fires, and the like may have been the cause of open spots within the exterior boundary lines; so that unless a careful survey has been made within the past few years, the accuracy of which is beyond question, it is necessary to ascertain by measurement with instruments the area occupied by the timber to be estimated. Under average conditions, this work can be done at a very moderate cost, and is the first step to be taken.

2. Instruments Used in Making a Survey. — The chief factor in determining the choice of instruments with which to make the survey is *cost*, which should always be reasonably proportional to the value of the property, and should be as low as possible, consistent with the degree of accuracy required by the nature and objects of the work. A survey made with instruments of precision, such as the transit, level, and plane table, would be far too costly in the case of the average farm woodlot or small piece of timber-land; these instruments can be used economically only on tracts of large size, *e.g.*, one thousand acres or more; much depending, even in such cases, on the value of the land and the timber. Such instruments as the small hand compass, however, are usually too inaccurate for survey work, except in the case of very small areas, or in the hands of an experienced surveyor who knows how to make allowances for the limitations of the small compass. Intermediate between these extremes, both in cost and in degree of accuracy, is the staff compass, usually equipped with a needle at least 2½ inches long, and enabling one to read bearings to the nearest half-degree. This is close enough for ordinary work and moreover, since the compass error in most forest survey work is not cumulative, it is possible to secure very satisfactory results with the staff compass. A description of this instrument is unnecessary here; for those who wish to consult articles on the surveyor's compass and its adjustments, a few selected references are given at the end of this chapter.

A compass serves merely to give *direction*. For the measurement of *distance* a surveyor's chain or a steel tape is needed. The former is 66 feet long, and composed of 100 links, each 0.66 foot (= 7.92 inches) in length. (See Table 1, page 226.) This unit of measure for distance is very useful in forest survey work because of the readiness with which square chains may be reduced to terms of acres. (See Table 2.) The steel tape may be graduated either in feet or in links, and has the advantage of being lighter in weight, and more easily handled, although it is at the same time more susceptible to damage. Both chains and steel tapes, the latter graduated to chains and links, are used extensively in forest surveys. For marking the chain- or tape-lengths in the measurement of lines, steel pins may be used; or stakes made of material picked up in the woods, to be discarded at the end of the work, are often just as satisfactory, and are much lighter to carry around.

To assist in the work of sighting the compass along a line, a rod or a staff is often a great convenience. Especially in the woods, where branches and foliage may obscure the view, a staff or rod painted with alternate bands of white and bright red will help in obtaining the sight quickly and easily. A cheap, handy substitute for the painted rod is a sapling which may be cut near by, and the bark peeled from it in alternate bands, in order to make it conspicuous. Or a white rag may be tied to the top of a straight sapling, and used successfully as a sighting rod.

Such accessories as note-books, pencils, crayons for marking stakes, hatchets or hand-axes, and other tools with which to accomplish the work of the survey, need no special comment; each one will adopt his own standards, and use such material as will suit individual tastes and the needs of the particular case.

(For further details of equipment and methods of measurement, the reader is again referred to standard textbooks on surveying, such as those mentioned at the end of this chapter.)

3. Methods. — The boundary survey of a woodlot or other piece of timber-land should begin, if possible, at some established point in the property the location of which is definitely described in the deed. If no such point exists on the border of the woodlot, the nearest point on the property so established should be chosen, and a line run from this point to the nearest corner of the woodlot. The bearing and the length of this line should be measured, thus establishing definitely the location of the woodlot with reference to a known point. It is now possible to make a traverse of the boundaries of the area to be measured and have it tied in to an established point.

A survey which ascertains the *direction* and *distance* of a line, or of a series of lines, or of a route, is called a *traverse;* and such a survey is generally made by commencing at some definite point and continuing by measured bearings and distances to the other points, one after the other; it may, or may not, return to the starting point. In the case of a woodlot the boundaries and area of which are to be determined, the traverse should begin at a known point and after going completely around the tract, return to the starting point, thus making a *closed* survey. For example, let us assume that the boundaries and area of the woodlot in Fig. 1 (page 5) are to be determined. The nearest established point, or corner, is the point *A*, which is on the property line, and is the northernmost corner of the woodlot. This corner is therefore selected, the staff-compass set up there, and the bearing and distance of the corner *B* (which is visible from *A*) determined with the aid of the compass and chain (or tape). This done, the compass is set up at *B*, and from this point it is now possible to obtain the bearing and the length of the line *B–C*; from *C*, it is possible to obtain the bearing and length of the line *C–D*; and so on, taking the corners *D*, *E*, *F*, *G*, and *H* in turn; finally the bearing and distance of *H–A* are obtained, which completes the traverse by returning to the point of beginning. The field notes for such a survey might well take the following form:

SURVEY OF WOODLOT ON THE SMITH FARM. *September* 2, 1915.

Description. — *A* is an iron pipe, 2 inches in diameter, set in the ground and marking a point on the property line. South corner of the house bears N. 70° W., 1.70 chains distant. South corner of barn bears S. 86° W., 3.68 chains distant.

TRAVERSE OF WOODLOT.

Station.*	Line.	Bearing.	Distance.	Remarks.
A	*A–B*	S. 66° 30′ W.	3.81 chains	
B	*B–C*	S. 23° 00′ E.	5.98 "	
C	*C–D*	N. 66° 30′ E.	1.28 "	
D	*D–E*	N. 39° 30′ E.	1.95 "	
E	*E–F*	N. 19° 00′ W.	0.79 "	
F	*F–G*	N. 23° 00′ E.	1.91 "	
G	*G–H*	N. 14° 00′ W.	1.03 "	
H	*H–A*	N. 45° 00′ W.	2.14 "	

---

* Any point that is occupied by the surveyor for the purpose of measurement of angles is called a "station." Stations are generally lettered alphabetically, or if there are very many of them, numbered consecutively.

If desired, a few descriptive notes may be added at the time the survey is made. They may be entered in the column "Remarks," or written more at length on the page of the book

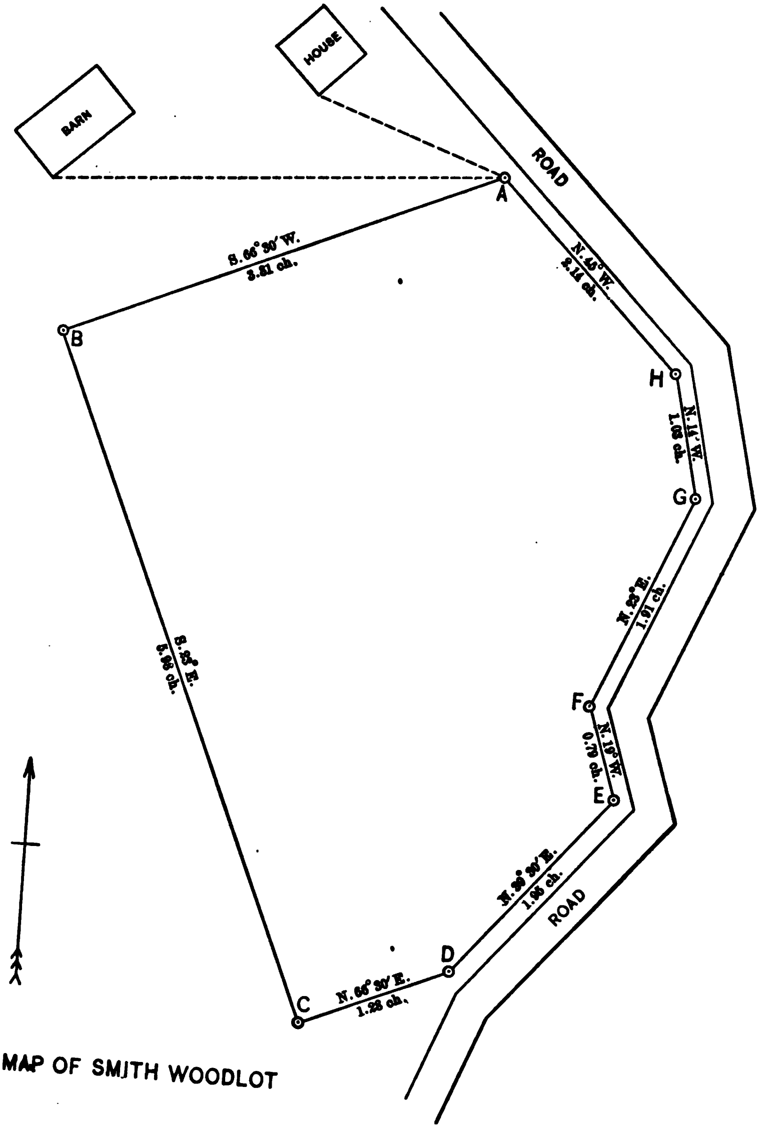


FIG. 1. Map of Smith Woodlot.

opposite the recorded measurements. It is customary to enter the figures for the angles and lines on the left-hand side of the note-book, reserving the right-hand side for descriptive notes and computations. The descriptive notes, if carefully written, frequently help to interpret properly the figures on the opposite page, or they may help to identify points used in conducting the work, should it become necessary to refer to the survey notes or marks at any time in the future. For example, the point *A*, which happens to be described with reference to the house and the barn, might also have been described with reference to two or more trees, which on account of their proximity and distinctive character would serve to identify the point should it become necessary to do so. In the same way, the point *B* might be described by referring to the south and the west corners of the barn, giving the bearings, but not necessarily the distances to these points. (Two or more bearings serve to locate a point, if they are not in the same straight line.) Reference marks should be chosen from among permanent objects if such objects are conveniently close.

Care should be taken to avoid setting up the compass too close to a wire fence, or any other metallic object which might deflect the compass needle, and give erroneous bearings.

A word should be added here regarding the measurement of land surfaces which are not level. All measurements of distance are to be made *horizontal.* If the surface of the ground is not level, the chain or the tape must be *held level*, and the measuring should be done in units short enough to make this possible. Thus, half a chain-length, or even ten links or less, may be taken as the unit in very steep country. For this work a plumb-bob will be found very useful. In going up hill, the plumb-bob is held by the rear chain-man; in going down hill, it is held by the head chain-man. If land surfaces are not measured horizontally, very unreliable results will be obtained, besides making it practically impossible to map the area correctly. (For detailed discussion of the measurement of lines and angles, measurement of slopes, etc., see text books referred to at the end of this chapter.)

Large obstacles, such as cliffs, rocks, bodies of water, etc., may be avoided simply by making the traverse run around them. The area may be corrected later on the map. Small obstacles, such as trees in the line of sight, may be gotten around most readily by off-setting. This may be done by moving the compass a known distance to the right or to the left of the line of sight, and at right angles to it, the off-set, as it is called, being made just large enough to clear the obstacle. The obstacle is passed by running past it on a line parallel to the original traverse line, returning to this line as soon as it is possible to do so conveniently.

4. Mapping. — It is always a great advantage to have an accurate map of any piece of property, no matter how large or how small. Forest land is no exception to this rule. A map conveys to the mind in a graphic way much information that is obscure when stated in terms of figures, dimensions, or directions, and often serves to correct misconceptions regarding relative locations and areas.

The *scale* to be selected should generally be the smallest that will serve the purposes of the map and permit the entry of all necessary data upon it without overcrowding. The following table shows approximately the scale suitable to tracts of different sizes, although it should be remembered that no strict rules can be given, for the purposes of maps vary so greatly

Area of tract	Scale of map.	
(Acres).	(Feet per inch).	(Chains per inch).
1 to 10	100	1.0
10 to 100	200	2.0
100 to 1000	500	5.0
1000 and upwards	1000	20.0

Much will depend upon the outline of the area and the amount of detail that must be shown on the map. It is rarely possible to show the details of topography, forest-cover, and cultural features on a scale smaller than 4 inches to the mile (1 inch = 1320 feet) unless there is great uniformity of conditions. Except under unusual circumstances, this scale should be regarded as the minimum for forest maps.

After an appropriate scale has been decided upon the next step is to draw the map from the field notes, according to this scale. For this purpose, the following articles are necessary:

1 Engineer's scale-rule.
1 Protractor, at least 2½ inches radius.
1 Straight-edge.
2 Triangles: one 45-degree, one 30–60-degree.
1 pair dividers.
1 or more hard pencils, at least 4 H.
A good grade of drawing paper, erasers, etc.
(A drawing-board, upon which the paper can be secured with thumb-tacks, together with a "T-square," makes the work of drafting considerably easier. These articles are not absolutely indispensable.)

There are two common methods of mapping, namely:

(1) The method of courses and distances.
(2) The method of latitudes and departures.

The first of these two methods consists in plotting the angles directly on paper, and scaling off the appropriate distances on the lines drawn. The second method requires computations before any plotting on the paper can be done. For each course, the distance east or west of a north-south line (meridian) must be computed, and likewise the distance north or south of the east-west line (base). Latitude is reckoned as the distance north or south of the base line, north latitudes being reckoned + and south latitudes −; departure is reckoned as the distance east or west of the meridian, east departures being considered + and west departures being considered −. As a matter of fact, it is quite common to compute the latitudes and departures for the several courses of a closed survey, even though this method is not followed in mapping, for, as will be shown in Article 5, a method is thereby furnished for eliminating the error of closure. For small areas, or where the field methods have been rather rough, because of the necessity for keeping the cost of the work low, it will rarely pay to employ the method of latitudes and departures. In these cases the method of mapping by courses and distances, correcting any errors which develop by simple methods, is clearly the most economical and satisfactory.

5. Plotting the Map by Courses and Distances. — Select a point on the paper for the initial point of the survey and through it draw a straight line which is to be the north-south line, *i.e.*, the meridian. The initial point should be chosen after an inspection of the notes to determine approximately how the map will appear on the paper, and so located that all the courses and distances may be plotted without danger of running off the paper. It is well to have a sheet of paper large enough to extend the meridian, and the lines parallel to it, to any distance required for easy handling of the protractor, triangles, and straightedge. Next, with the protractor placed carefully along the meridian and centered over the initial point, mark the bearing of the first course, and draw a line from the initial point through this mark, extending it a sufficient length to scale off the distance. Since *direction and distance* fix a point, we now have established on paper the position of the second station occupied in the survey. Through this point now draw a second meridian, *parallel to the first one*, and repeat the process just described, to locate the position of the third station. The process is repeated again and again, until the last station has been located. If the field-work, note-recording, and plotting have all been perfectly accurate the last course should strike the point of beginning and its scaled distance should be equal to the distance called for in the field notes. If there is an *error* in either the field-work, the note-recording, or the plotting, the survey will fail to "close," as it is called, — *i.e.*, there will be a discrepancy between the point of beginning and the point of ending, as shown on the map. The work must, therefore, be examined critically to see if any errors can be detected. The map should first be inspected; if there has been no mistake in laying off the angles and scaling the distances on the map, and if the error of closure is large, it is probable that there is an error in the field-work, which can be corrected only by a re-survey. Bearings may have been read wrong, or distances may have been measured incorrectly, and such mistakes would of course make it impossible for the survey to close. If the error of closure is small, however, it may be assumed that the angles were read as closely as possible on the compass, and the distances measured accurately; the field-work is, therefore, acceptable. Making allowances for the facts that angles cannot be read closer than one-half degree on the average staff compass, or plotted any closer than one-half degree with the average protractor of 2½-inch radius, we may consider a slight error in closure as permissible. This error, which may be reckoned in terms of percentage, by scaling the error of closure and comparing it with the total length of all the courses, may be, for work in the woods with compass and chain, as much as one-half of one per cent, or 1 in 200, without seriously affecting the results in determining area. If a degree of accuracy greater than this is required, then instruments of greater precision should be used. It is impossible to perform absolutely perfect work, and the instruments chosen should be consistent with the degree of accuracy and refinement required by the work.

The error, as determined, should be distributed in some way, and eliminated. We may assume, for example, that if all the courses presented about the same conditions, no one of them being more difficult of measurement than any of the others, the error is likely to be quite evenly divided among all the courses. We can, therefore, distribute the error in proportion to the length of the several courses. One way of doing this is extremely simple and easy of application, and will be described here because it can be used to advantage in most surveys of small area, with comparatively few courses. It may be called the graphic method.

Since the error is undoubtedly composed of two parts, namely, errors in angular measurement and errors in linear measurement, the correction must take into consideration both angles and lines. If it is assumed as above, that the error is proportionate to the length of the courses, then it may be distributed by drawing the line which represents the closing error (the line *E–A* in Fig. 2) and scaling it; next, draw lines parallel to this closing error line from each station (see Fig. 2) and scale off, on these lines, the proportional part of the error, found by comparing the length of each course with the total length of all courses. For example, in Fig. 2, where, for the sake of clearness, the error has been greatly exaggerated, suppose there are four courses, *A–B*, *B–C*, *C–D*, and *D–A*, and in plotting the map the error *E–A* is found.

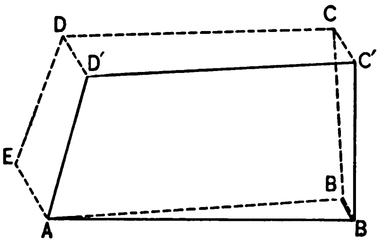


FIG. 2. Graphic Method of Distributing the Error in Surveys.

A–B	2.40 chains
B–C	1.25 chains
C–D	2.25 chains
D–A	1.10 chains
	7.00 chains, total length of all courses.

Error = *E–A* = 0.50 chain.

Error to be distributed as follows:

A–B	= 34 per cent	of 0.50	chain	= 0.17 chain.
B–C	= 18 per cent	"	"	= 0.09 chain.
C–D	= 32 per cent	"	"	= 0.16 chain.
D–E	= 16 per cent	"	"	= 0.08 chain.
	100 per cent			= 0.50 chain.

Lines are then drawn parallel to *E–A* from *B*, *C*, and *D*, and the distances,

0.17	= 0.17 chain,
0.17 + 0.09	= 0.26 chain,
0.17 + 0.09 + 0.16	= 0.42 chain,
0.17 + 0.09 + 0.16 + 0.08	= 0.50 chain,

scaled on them, respectively, so as to bring the corrected corners at the points *B′*, *C′*, and *D′* as shown. If these points are now connected, the survey closes, and it may be accepted as representing, ***approximately***, the angles and distances as they actually appear on the ground. It must be remembered that in case the error exceeds the ratio 1 : 200 the field-work had better be done over again in order to eliminate errors of measurement.

Those who have a knowledge of mathematics sufficient to apply the method of latitudes and departures will find that method a very good one to use, for it not only gives an opportunity to correct and balance errors in the most satisfactory way, but it makes the task of plotting the map easier. A further advantage of the method of latitudes and departures is that with these quantities known area may be determined easily by the method of Double Meridian Distances. This method is described in standard works on surveying, to which reference has already been made.

Having adjusted the lines and corners so that the survey closes, it may be taken for granted that the outline map resulting represents with sufficient accuracy for the purposes in mind the size and shape of the woodlot, drawn to scale. The addition of details, such as streams, roads, and ponds, and all cultural features, also topography and forest types, will be possible after other surveys incident to the timber estimate have been made; and it is needless to add that the same scale should be used in entering these details upon the map.

6. Area. — If the traverse is composed of relatively few straight lines an easy way of obtaining the area of the land mapped is to divide it into a number of triangles (the number always being two less than the number of sides to the figure) and then find the area of each triangle separately by scaling the bases and the altitudes, and applying the well-known formula; then add together the areas of the several triangles, thus finally obtaining the area of the entire tract. (See Appendix, Table 3, Area of Triangles.)

If the traverse is composed of a great many lines, or if any of the boundary lines are crooked (*e.g.*, the banks of a stream, or lake), by far the easiest way of obtaining the area is to use a planimeter, an instrument which will be found described in standard books on surveying. Another, but extremely rough, method of determining area is to place over the drawing a thin piece of tracing paper, on which squares are drawn, representing a unit of area, say square rods, or square chains. The number of squares lying within the boundary of the area can then be counted, — first the full squares, then approximating the fractional parts of squares, as nearly as may be, — thus enabling one to get the area at least approximately. This method is at best only rough and rather inaccurate, and should be employed only as a last resort.

7. Costs. — As stated in Article 2, the cost of mapping and estimating timber should be kept as low as possible, consistent with the degree of accuracy demanded by the nature and the objects of the work. It would be folly to spend $100 in mapping and estimating a piece of timber worth only $500, and while no inflexible rule can be laid down, it might be said that on large areas (10,000 acres or more) it will generally be considered unwise to spend more than two cents per acre for this part of the work, *i.e.*, boundaries and area. On smaller tracts, the following figures may be taken as a guide:

Size of tract.	Limit of cost of boundary survey.
10 to 100 acres	$0.05 to $0.10 per acre
1000 to 10,000 acres	$0.03 to $0.04 per acre

Everything depends on the value of the land and the timber. On the basis of *values*, it will rarely be wise to spend more than from two-tenths of one per cent to five-tenths of one per cent (0.2 to 0.5 per cent) of the combined value of the land and timber in making an outline map from which the area can be determined and on which the timber-estimating strips may later be entered. (See Chapter VIII.)

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CHAPTER II

FOREST MENSURATION

8. Definition of Forest Mensuration. — Forest Mensuration is that branch of forestry which deals with the determination of the volume of stands, trees, logs, and other timber products, and with the study of growth and yield of trees and stands.*

The measurement of any article implies the use of one or more units that are accepted throughout a given region or country as *standards*. This is necessary to facilitate buying and selling the commodity. Many of our weights and measures are standardized by state or federal laws and in like manner some of the standards for the measurement of logs and lumber have been approved by legislative bodies, and declared legal, or standard, for a given state. It is unfortunate, however, that owing to the great variety of uses for wood, and the lack of uniformity in the specifications for certain pieces in different localities, there has grown up not only a long list of units of measurement for wood, but the commonly accepted meaning of these units is not always the same in all parts of the country. Moreover, the stems of trees, from which lumber is produced, display a great difference in straightness, degree of taper, and quality; so that in the process of manufacturing lumber from logs, the proportion of sound, merchantable lumber which can be produced varies greatly. Thus, from two trees of the same height and the same diameter, but of different form, the amount of lumber produced from the straight, cylindrical tree will exceed that produced from the crooked or misshapen tree with quickly tapering trunk. The amount of lumber obtainable from these two trees will also depend on a number of other factors, as noted in Articles 12 and

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* Throughout this book, terms are defined in accordance with the nomenclature and definitions adopted by the Society of American Foresters. See "Journal of Forestry," vol. XV., No. 1, January, 1917. This is the official organ of the Society of American Foresters.

13, and it should be understood at the outset that for no other class of material, perhaps, is there such a wide range in the number of different units of measurement, and in their application. In this respect, lumber and wood products are almost unique. The more important of these units will now be discussed.

9. Units of Measure — (*a*) *The Board Foot.* — This is the commonest unit of measure for lumber in general use. It is used both to measure sawed lumber, and to express the estimated merchantable contents of logs, trees or stands. It is defined as a board one foot long, one foot wide, and one inch thick, or its equivalent. It is customary to speak of board feet in terms of thousands, because lumber is generally handled in large quantities in the market; when so spoken of, the Roman numeral M is used as an abbreviation. For example, hemlock may sell in a certain market for $18 per M, and this means that one thousand board feet of hemlock lumber, whether in inch boards or two-inch planks, or "two-by-fours," or other dimension timbers, cost $18.00. The rule for determining the board-foot contents of any regular piece of sawed lumber may be stated as follows:

Multiply together the width in inches, the thickness in inches, and the length in feet; divide this product by 12.

Example: (1) A board 1 inch thick, 8 inches wide, 12 feet long:

$$\frac{8 \times 1 \times 12}{12} = 8 \text{ board feet.}$$

(2) A plank, 10 inches wide, 2 inches thick, and 16 feet long:

$$\frac{10 \times 2 \times 16}{12} = 26\tfrac{2}{3} \text{ board feet.}$$

(3) A piece of dimension stuff, 10 inches wide, 6 inches thick, 14 feet long:

$$\frac{10 \times 6 \times 14}{12} = 70 \text{ board feet, etc.}$$

It will sometimes be found upon close measurement that planks and dimension timbers do not fully measure up to the thickness called for. They may lack $\frac{1}{16}$ of an inch, more or less, of being the full size. The reason for this is that green lumber shrinks, and not all mills adjust their saws to allow for this shrinkage. To make proper allowance for shrinkage, boards to be one inch thick when seasoned, should be sawed slightly thicker, *e.g.*, $1\frac{1}{16}$ inches. (See Chapter III.) Again, if inch boards are planed on one or both sides, or if flooring is tongued and grooved, so as to match properly, the pieces will be slightly less than the full inch in thickness, and less than the specified width; nevertheless they are reckoned as full size because, in the beginning, a piece of lumber of full size was used to produce the finished, planed board. These slight differences are understood and accepted in the trade.

As an aid to the ready determination of the board-foot contents of a piece of manufactured lumber of any size, lumber dealers and inspectors use a special stick called a "board rule," which shows at a glance the board-foot contents of a piece of lumber when the width, thickness, and length are known. Board rules simplify the labor of calculating board-foot contents of lumber, and are especially useful in measuring large quantities of boards which run in a great variety of widths and lengths.

(*b*) *The Cord.* — Perhaps the next commonest measure for wood is the cord. Fuel, pulp-wood, and the like are generally measured by this unit, which is a convenient one for sticks that are too short, or too small in diameter, or too irregular to be scaled by the board foot. A cord is defined as a pile of stacked wood 8 feet long, 4 feet wide, and 4 feet high. It is customary to saw the individual pieces into 4-foot lengths, and to pile them transversely to the 8-foot dimension as compactly as possible. A cord of standard size contains 128 cubic feet of stacked wood, although the actual solid cubic contents rarely exceeds 90 cubic feet. This number varies considerably, as is shown in Appendix, page 227. Sometimes wood in lengths much shorter than 4 feet is stacked into a pile 4 feet high and 8 feet long, and sold as a cord. Thus, wood for small stoves is often cut into 18-inch, 16-inch, or even 12-inch lengths, and a stack of such wood, 8 feet long and 4 feet high will be called a cord. Such practices, however, are understood, and the price of these so-called "short cords" is adjusted accordingly.

(*c*) *The Cubic Foot.* — The use of the cubic foot as a unit of measure is not common in commercial practice in this country, except in the measurement of rare and costly woods. As wood becomes less plentiful and rises in value, it is quite possible that the cubic foot will be used more and more as a commercial unit; but for the present it is confined largely to calculations of growth and yield, by foresters and lumbermen who are planning on a definite system of forest management. Long-continued usage has made the board foot and the cord the two commonest units of measurement, and they will doubtless continue so for a long time to come, for the reason that everybody is thoroughly familiar with these units.

(*d*) *Standards.* — A peculiar unit of measurement which is a relic of the early days of lumbering in the Adirondack Mountains of New York is the "standard," or "market," which, in the particular locality mentioned is a log 13 feet long and 19 inches in diameter at the small end. Other standards are the 22-inch standard, sometimes called the Saranac River Standard Rule; the 24-inch standard; and some others of less general usage. With the exception of the Adirondack standard, they are commonly based on a log of 12 feet. They may all be expressed mathematically by the general formula:

$$V = \frac{d^2}{D^2} \times \frac{l}{L},$$

in which d and l are the diameter and the length, respectively, of the log to be measured; and D and L the diameter and the length respectively of the standard log. V expresses the contents in *standards*.

Example: A log 16 feet long, 21 inches in diameter, by the Adirondack standard, would contain 1.5 standards, or markets, derived as follows:

$$\frac{(21)^2}{(19^2)} \times \frac{16}{13} = \frac{441}{361} \times \frac{16}{13} = \frac{7056}{4693} = 1.5 \text{ (nearly).}$$

To convert this into terms of board feet it is necessary to know how much the standard, or market, itself scales by some accepted log rule. In the case of the Adirondack 19-inch standard, the scale is about 200 board feet, depending on what log rule is used. (Doyle gives 183; Scribner gives 195; and Clark's "International" Rule, reduced to a kerf of one-fourth inch, gives 208 board feet.) These range close to 200 and it is, therefore, common practice to consider five (5) standards or markets of this particular size equivalent to one thousand board feet, and the relation is expressed: "5 standards to the M."

In New Hampshire a rule known as the Blodgett Rule, which is really a standard rule, and which has been adopted as the statute rule of that state, is based on a unit log one foot long and 16 inches in diameter. Theoretically this unit is considered equivalent to one cubic foot (it is actually equal to 1.396 cubic feet) and it is also considered as producing 10 board feet. Logs of all other dimensions are referred to this as a unit. In practice, it has been found that the amount of lumber which a Blodgett foot will yield depends on the diameter of the log, and whether it is measured in the middle, or at the small end. Locally, the lumbermen and woodsmen who are familiar with the rule recognize 115 "Blodgett feet" as equivalent to 1000 board feet, if the logs are measured at the middle, and 106 "Blodgett feet" equivalent to 1000 board feet, if the logs are measured at the small end.* This subject is discussed more in detail in Chapter III, which treats of Log Rules.

(*e*) *Poles, Posts, Railroad Ties, and Other Pieces.* — Pieces of timber which satisfy certain standards as to size, length, girth, etc., are generally sold by the piece. Thus, in the East, the commonest of such units are the following: poles, posts, ties, and in mining districts, props, stulls, lagging, etc. In some parts of the West there are still other units, such as converter poles, shakes, etc. A table showing the equivalents of these units in board feet will be found in the Appendix, page 226. While in some localities these units are used more or less loosely, nevertheless the markets, especially for ties and poles, are usually quite definite in their specifications. Moreover, the pieces are subject to rigid grading and inspection rules, so that the quality of the piece influences to a very large degree the market price. The usual specifications for some of the commoner pieces are as follows:

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* See Graves, H. S.: "Forest Mensuration," page 55.

R. R. ties, standard gauge, 8 feet x 8 inches x 6 inches.
R. R. ties (recent specifications by some railroads), 8½ feet x 9 inches x 7 inches.
Poles, top diameter, 7 inches; lengths, 20, 25, 30, 35, 40, etc., feet.
Posts, 7 feet long, and a specified diameter, or girth, at the top.

(*f*) *Linear Foot.* — Pieces of very small girth, too small to be measured by the board foot, yet straight enough to find a use in some industries, may be sold by the linear foot, or running foot as it is often called.

There are still other units used for certain articles of manufacture, but they are generally of sizes determined by local conditions. Thus in some parts of the country blocks of maple or beech find a ready market for manufacture into shoe-lasts. These blocks are furnished in sizes specified by the manufacturers. Material for making wheels (spokes, hubs, and felloes) and the parts of agricultural and sporting implements are often required to meet certain specifications, and these must be made to conform to the local demands. No hard and fast dimensions can be given.

10. The Need for Standards of Measurement. — From the foregoing articles it is plain that there is a great multitude of units for the measurement of wood products in this country, and that some of these units, going by the same name in different localities, may nevertheless have different dimensions and contain more or less wood. The confusion which follows as a result is greatly to be deplored, for it often makes it impossible for buyer and seller properly to appraise stumpage. Some definite standards, to be acknowledged as such in all parts of the country, are urgently needed, and the adoption of such standards would do much to eliminate the sense of uncertainty which pretty generally surrounds any deal in standing timber nowadays, whether the amount be large or small. While the use of many of the commoner units, such as the board foot and the cord, will doubtless persist for many years, it is to be hoped that some day the use of the cubic foot (or, if the metric system should be adopted in this country, the cubic meter) will become general. This will bring about a standardization very desirable both from the standpoint of the buyer and the seller of timber and lumber, and especially from the standpoint of the forester, who must deal not only with wood products that are manufactured, but with growing trees and forests, whose volumes and values are constantly changing.

There are so many units of measure, and so much variation in the method of applying the several units, that it is extremely difficult to formulate any table of comparisons. Nevertheless, comparisons, although not exact, are often useful when compiling statistics, and a table of converting factors has therefore been included in the appendix. (See page 226.)

CHAPTER III

LOG RULES

11. Definition. — In buying or selling standing timber or logs, it is necessary to have some means of determining about how much lumber can be obtained from them after sawing. Most standing timber is bought or sold on the basis of an estimate, and this estimate is usually made in terms of thousands of board feet, board measure — expressed "M. feet, B. M." Or, if logs are bought or sold, the price is quoted at so much per thousand feet, board measure (M. feet, B. M.), and the logs are measured, or scaled, to determine approximately the number of board feet of lumber they will yield when sawed. In the case of standing trees, the only things that can be measured are the diameter (usually at breast-height, — that is, 4½ feet from the ground) and the height — either the total height, or the merchantable height; and since the taper, crooks, thickness of bark, and soundness of a standing tree cannot be measured directly, but can be judged only by the eye, it follows that the estimate of the merchantable contents thus made is decidedly approximate, and often exceeds or falls short of the actual sawed product by as much as 10 per cent or 20 per cent. Experience and familiarity with the trees of a region soon lead to considerable accuracy on the part of careful estimators, but the results are always *approximate.*

In the case of felled trees and logs there is the advantage that certain additional measurements can be made, and the estimate of the contents of the tree or log can, therefore, be made much more closely — usually within 5 per cent. The length, diameter, thickness of bark, any eccentricities or crooks, and any visible unsoundness can be measured or observed, and then by reference to a standard table of values, the board-foot contents can be estimated. It is still an *estimate*, however, because no one can tell positively what the saw will disclose in the interior of the log; and the degree of unsoundness or other defect will, of course, influence the final product. The table of values referred to above is called a *log rule*, and may be defined as follows: *A Log Rule is a tabular statement indicating the estimated or calculated amount of lumber which can be sawed from logs of given lengths and diameters.* The tabular statement is generally arranged in columns, the board-foot values being printed in horizontal lines opposite the left-hand column of numbers representing diameters in inches, and under the numbers 8, 10, 12, 14, 16, 18, 20, etc., representing the standard lengths of logs in feet. (See Appendix, Tables 6 and 7.)

There are a great many log rules in use, and for convenience in scaling logs the values of any particular rule are usually printed on a stick, graduated to inches, showing for logs of any given diameter and length the corresponding contents in board feet. Such a stick is called a scale stick, and is made in a variety of forms, some of which are shown (Fig. 3, page 23).

That the board-foot as a unit of measure for sawed lumber has been in use for over a century is shown in a very interesting discussion on the early history of log rules, by H. S. Graves, Forester, U. S. Dept. of Agriculture.* The early rules were based either on a rough mathematical formula, — often the result of repeated trials, and hence, really empirical, — or on diagrams, drawn to scale, representing the cross-sectional view of a log sawed into inch boards. The contents of logs of different sizes were then computed from these diagrams, applying the rule for finding the contents of sawed lumber, given on page 15.

12. Methods of Constructing Log Rules. — Log Rules may be constructed in any one of three ways, namely:

(1) By diagrams drawn to scale.
(2) By mathematical formulæ.
(3) By mill scale studies.

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* Graves, H. S., "Forest Mensuration," pages 22–26, New York, John Wiley and Sons, Inc., 1906.

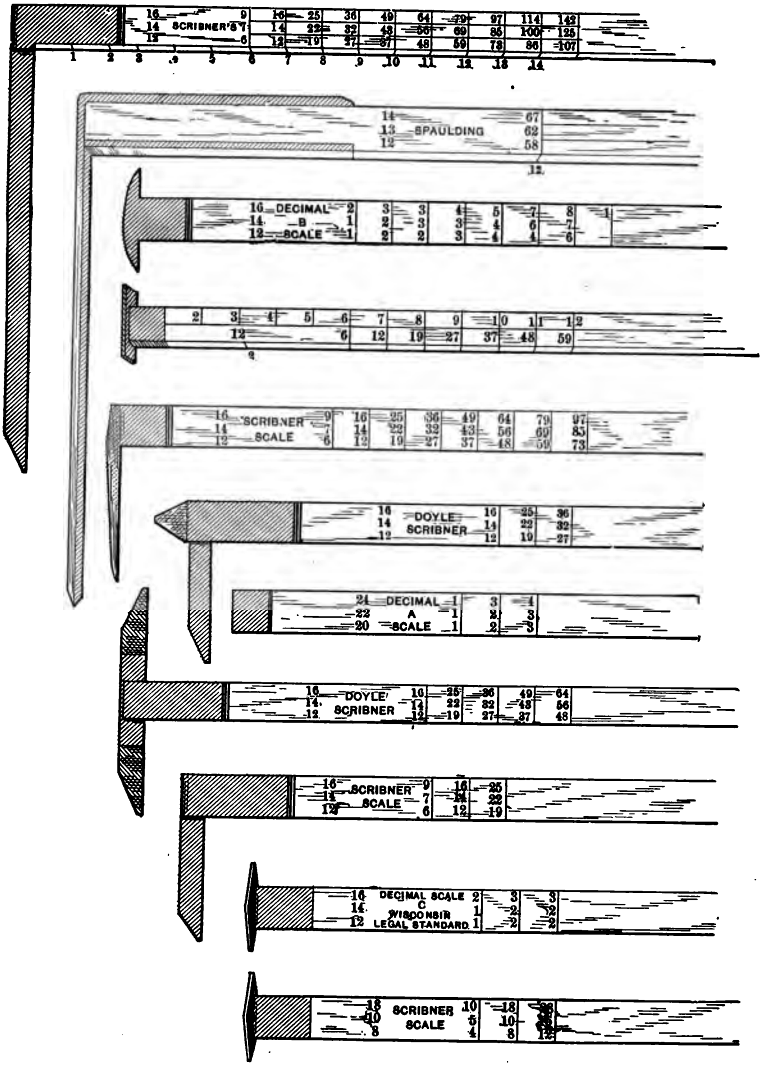

Fig. 3. Various Forms of Scale Sticks.

Of course it is possible to modify the results obtained by either of the first two methods, by applying a correction factor, as found under method number 3, where logs of known size are followed through the mill, and the sawed product measured as lumber. As a matter of fact, nearly all mathematical formulæ for constructing log rules contain a factor of correction which is based on observation at the mill and is purely empirical. In other words there are certain losses, due to normal crook and taper, the allowances for which can be determined only by following an average lot of logs through the mill. All of the mathematical formulæ which are based on sound principles contain such a factor.

(1) *Log Rules Based on Diagrams.* — The earliest log rules, as mentioned in Article 11 were diagrammatical. Circles were drawn for every inch-size, from 12 to 44, or more, and then beginning at one side of the circle a segment (slab) with a 6-inch side was first cut off; next, an allowance for saw-kerf was made (in the old rules, this was at least one-quarter of an inch) and then an inch board was cut off. This process was continued until all the available part of the circle was used, which would make a board 6 inches wide. Then the round edges (wany edges) were trimmed off in the diagram, and the board foot contents of the standard size logs — 8, 10, 12, 14, 16, etc., feet — calculated by the rule already given. (See page 15.) Later, as logs smaller than 12 inches in diameter became merchantable, the log rule values for sizes 6 to 11 inches, inclusive, were calculated, and incorporated in the table.

It is possible, of course, to draw diagrams for all sizes, allowing for a kerf other than one-fourth inch, and for boards with smaller merchantable widths. Thus, if it were desired to construct a rule to be used where a band-saw taking out a kerf of one-eighth inch is employed and where boards as narrow as 3 inches are merchantable, the diagrams could be drawn accordingly, and a rule constructed that would give accurate results *when used under those particular conditions.* Before attempting to use any log rule, it is wise to discover upon what basis it is constructed, and how it is applied, so as to be able to judge of its applicability to particular conditions.

(2) *Log Rules Based on Mathematical Formulæ.* — Logs from normal, sound trees approach pretty closely in form certain geometric solids (see Chapters V and VI), and since the contents of these solids can be found by applying appropriate formulæ it follows that the board-foot contents of these solids can be found by applying formulæ in which correction factors are introduced for taper, saw-kerf, slabs, edgings, normal crook, and (as some authors claim) for shrinkage.

If they pretend to any accuracy, mathematical formulæ for determining the board-foot contents of logs begin with the fundamental formula for the contents of a cylinder, as given in solid geometry. This formula, it will be remembered, is simply the area of the base, B, multiplied by the height H; or, in terms of the diameter of the base, D, and the height, H, the formula becomes:

$$\frac{\pi D^2}{4} H = 0.7854\, D^2 H.$$

In the case of logs, D is expressed in terms of inches and H in terms of feet. In order to obtain a formula which will give us the number of board feet in such a cylinder, we must first reduce H to terms of inches, which is done by multiplying by 12. Then, since the ratio between board feet and cubic inches is 1 : 144, it will be necessary to divide the product, $D^2 \times H$, which is in terms of cubic inches, by 144. We then have, as the formula which expresses the board-foot contents of a cylindrical log ***when no allowance is made for slabs, saw-kerf, and other losses,***

$$(0.7854\, D^2 \times H \times 12) \div 144 = \text{board feet.}$$

It will be observed that when $H = 12$, the formula reduces, by cancelation, to a very simple expression, namely:

$$\text{Theoretical board feet of a 12-foot log} = 0.7854\, D^2.$$

(*no allowance for slabs, kerf, etc.*)

Another way of expressing this is as follows: Since a board foot is equivalent to 144 cubic inches, then in a 12-foot log, every square inch on the base represents a board foot, *i.e.*, the square inch at the base multiplied by 12 feet (= 144 inches) will give 144 cubic inches. On account of this relation, nearly all mathematicians have used the 12-foot log as the standard on which to base their computations, and after making certain allowances for saw-kerf, slabs, etc., they have simply multiplied the results for any given inch-class by $\frac{H}{12}$ to find the values for logs of the same diameter, but of lengths other than 12 feet.

Since there are certain losses, such as slabs, saw-kerf, and some others to be noted presently, by which the board-foot contents of logs are affected, there must be certain corrections applied to the fundamental formula for a 12-foot log, $0.7854\ D^2 \times H$, which, as we have seen above, is the starting point.

In the first place the width of the smallest board which can be considered merchantable will determine the width of the slabs which must be taken off. The increased demand for lumber together with the rise in price and the general effort now being made to reduce waste so far as possible, has made it practical to use boards as narrow as 3 inches, and this width has been used as a minimum by many recent writers in their work of calculating the contents of logs. The edgings also constitute a loss of material which can be classed with the slabs, and since the more boards a log produces the more edgings will it be necessary to account for, it will be noted that *slabs* and *edgings* are two sources of loss which depend on the size of the log; they are, as a matter of fact, proportional to the "barked area" of the log, as has been shown by Mr. H. E. McKenzie.*

Secondly, since no logs are perfectly straight and symmetrical, there is a loss due to normal crook which must be allowed for. Thirdly, there is a loss in saw-dust. The saw in passing through a log leaves a path that is spoken of as the *saw-kerf;* the material lost in this manner is saw-dust. This loss is proportional to the cross-sectional area of the log, *i.e.*, D^2.

Again, the *taper* of the log is a fourth factor which must be taken into account, especially in the longer standard lengths.

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* McKenzie, H. E., "A Discussion of Log Rules," California State Board of Forestry, Bulletin 5, 1915, page 17.

Logs are scaled at the small end, therefore taper, if it be pronounced, or if the log be long, will make it possible, under certain circumstances, to obtain more lumber from a tapering log than from a cylindrical log. Dr. J. F. Clark[*] was, perhaps, the first to recognize this factor and allow for it in his "International" Rule.

A fifth factor is the average dimensions of the lumber sawed. It is very obvious that a log sawed into two-inch planks, or larger dimension stuff will yield more than the same-sized log sawed into inch boards, for the simple reason that the loss in saw-kerf is less. Most log rules are constructed on the theory that 1-inch boards are to be sawed; scalers and mill men have learned to allow for an overrun if much dimension stuff is produced.

Dr. Clark in his discussion[*] argued that shrinkage should be a legitimate factor. To quote him:

> "A point that has been overlooked by some rule makers is that the scale given should refer to the amount of *seasoned* inch lumber which can be sawn from the logs scaled. Inasmuch as logs are ordinarily scaled green, it becomes necessary to allow for the shrinkage of the boards in thickness and in width which accompanies the seasoning. The margins of safety adopted by different mills vary considerably, but usually run from $\frac{1}{8}$-inch to $\frac{3}{8}$-inch in the width of the boards, and from a scant $\frac{1}{20}$-inch to $\frac{3}{32}$-inch in thickness."

Summing up, the factors which should be taken into account in constructing a mathematical formula which give the board-foot contents of a log of given dimensions are six in number:

(1) Slabs and edgings.
(2) Normal crook.
(3) Saw-kerf.
(4) Taper.
(5) Average dimensions of lumber sawed.
(6) Shrinkage.

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[*] Clark, J. F.: "The Measurement of Saw Logs." Forestry Quarterly, IV, No. 2, 1906, page 79.

(3) *Empirical Rules.* — If logs are followed through the mill and a tally kept of the exact amount of lumber produced from each one, it is possible by this means to secure a set of values for a log rule which are based entirely on the *average production*, and hence, empirical. Such a table of values would be useful locally; and they could also be used for the determination of a correction factor, to be applied to any recognized rule so as to obtain more accurate results in scaling. Thus in Arkansas, where the Doyle Rule is the statute rule of the state, there are many mills that apply a correction factor to the scale, varying with the size of the log, because their *experience* tells them that the Doyle Rule underestimates the contents of small logs, and overestimates the contents of the larger logs. While they use the Doyle Rule, and thus conform to the law of the state, they are, in effect, using an empirical rule, because, based on their experience, they make allowances, correcting the Doyle Rule where they know it fails.

In Article 14 the rules commonly known are classified and commented upon briefly.

13. Application of Log Rules. — It must be remembered that log rules show the estimated contents in board feet of *sound* logs, which are reasonably straight and free from excessive taper, and which are sawed by skilled men. No allowance is made for defect or wasteful sawing, and this is the only safe method to adopt, otherwise it would be impossible to credit a sound log with its full scale. In all cases, defect is allowed for in the process of scaling, by considering the logs as though sound, and then making a proper deduction for the visible defect, plus a further deduction for invisible defect, if this appears necessary after observing the product of average logs at the mill.

14. Comment on Existing Log Rules. — The following list of log rules includes those described in Graves' "Forest Mensuration" (1906) together with a few others more recently described.* They have been grouped, so far as possible, into the three classes recognized, the mathematical, the diagrammatic, and the empirical. Where the origin is unknown, a separate class has been made. Those rules that have enjoyed a use wide enough to prove their merit are followed by the sign (†); those that are mainly theoretical, and, although based on sound principles, have not been tested under conditions sufficiently diverse to prove their practicability, are followed by the interrogation-point (?); those about which little is known, or which have not been used extensively, are left unmarked. Where there is any further comment, it will be found under "Comments" following the number corresponding to the list-number.

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* See Forestry Quarterly, Vol. VII, page 144.

Classification of Log Rules

Mathematical.	Diagrammatic.	Empirical.	Unknown.
(1) Champlain (?)	(22) Scribner †	(29) Chapin	(32) Drew
(2) Universal †	(23) Maine †	(30) Boynton	(33) Quebec †
(3) International †	(24) Hanna †	(31) Massachusetts	(34) New Brunswick†
(4) Doyle †	(25) Spaulding †		(35) Dusenberry
(5) British Columbia †	(26) Baughman		(36) Northwestern
(6) Constantine (theoretical)	(27) Favorite		(37) Derby
(7) Vermont †	(28) Herring (= Beaumont)		(38) Partridge
(8) Baxter			(39) Parsons
(9) Two-thirds Rule (= Tennessee River Rule)			(40) Stillwell
(10) Square of ¾ Rule (= Portland = Noble and Cooley = Cook = Crooked River = The Lumberman's Rule)			(41) Saco River
(11) Cumberland River = Evansville = Third and Fifth Rule			(42) Wilson
(12) Orange River = Ochiltree Rule = Sabine River Rule			(43) Ballon
(13) Preston			(44) Wilcox
(14) Ropp			(45) Warner
(15) Forty-five Rule			(46) Carey
(16) Ake			(47) Younglove
(17) McKenzie (?)			(48) White
(18) Tiemann (?)			(49) Finch and Apgar
(19) Clement's Rule			Combination, mathematical and diagrammatic
(20) Click's Rule			(50) Doyle-Scribner †
(21) Calcasieu Standard			

Comments

(1) Values run high, except where used with a band saw.

(2) Gives good results for average logs, where a circular saw cutting ¼-inch kerf is used.

(3) Gives good results where logs are utilized closely. Can be adapted to saws taking out ¼-inch kerf, by reducing the table values by 9.5 per cent.

(4) Values run too small on small logs, and too high on very large logs.

(7) Unsatisfactory; too large for small logs.

(17) A new rule, described in the California State Board of Forestry Bulletin 5. Very carefully worked out, and adaptable to any conditions by changing the formula slightly. Not in common use.

(18) Theoretical. Not in actual use.

(22) One of the commonest and most widely used of all rules. In a modified form, where the units are rounded off to the nearest 10, and the final cipher dropped, it has been adopted by the U. S. Forest Service, as the official rule. In the form thus described it is known as the Scribner Decimal "C" Rule. While its values are very conservative, it gives satisfaction, in most cases, for by careful sawing, average logs will produce slightly more than the rule gives.

(23) Satisfactory for logs of short length.

(24) Much like the Scribner Rule.

(47) For an account of this rule, see Forestry Quarterly, XII, page 395.

CHAPTER IV

INSTRUMENTS FOR FOREST MEASUREMENTS

The measurement of area has been discussed in Chapter I, and the instruments used in that work have already been referred to specifically. It remains now to discuss some of the instruments which are peculiar to forest work. While the principles involved in some of these instruments have been used in many other arts and sciences, nevertheless, the requirements of forest work have created a demand for some instruments of a specialized character, peculiarly adapted to the needs of foresters and lumbermen.

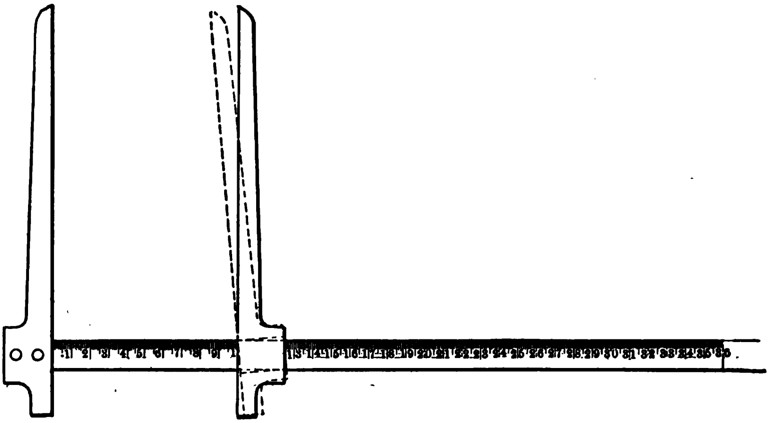

FIG. 4. Tree Calipers.

15. Forest Instruments. — Foremost among these instruments is the *tree caliper*. The most commonly used dimension of a tree or a log is the diameter, and this is obtained most readily with the aid of calipers, a common style of which is illustrated in Fig. 4. A hardwood beam, measuring approximately 37 inches long, $1\frac{1}{2}$ inches wide, and $\frac{3}{8}$ inch thick, is graduated on both sides to inches and *tenths* of inches, from 0 to 36.* At the 0-end of the beam is attached a fixed jaw, set at right angles to the graduated beam. A second jaw, which is movable and slides along the graduated beam by means of a metal-lined slot, is so constructed and adjusted that it has play enough to move easily, but when applied to the tree in making a measurement, it assumes a position perpendicular to the graduated beam, on which the diameter of the tree may then be read, directly from the scale. The metal plates lining the slot in this movable jaw are adjustable by means of screws, so that in case the jaw, by continued use, or changes in the wood due to moisture, should fail to assume a perpendicular position, the error can be eliminated by loosening the screws just mentioned, and re-adjusting the plates. The movable jaw can be slid off the beam, and the fixed jaw is demountable by means of two screws; so that the instrument can be taken down and arranged compactly for shipment or transportation. The standard size tree caliper (36-inch) weighs but 30 ounces, and is extremely portable and convenient. During the last few years, the so-called "Biltmore Stick" (see Article 20) has to some degree displaced the caliper in work of timber cruising where diameters to the nearest inch-class only are required; but the Biltmore stick, even when used with great care, is less accurate than calipers, and in any work requiring a degree of refinement closer than whole inches, the caliper, graduated to tenths of inches, is indispensable.

For measuring the diameter of very large trees, or for measuring and re-measuring diameters of trees on permanent sample plots, a *circumference tape* is recommended. This is a steel tape so graduated that when placed in a position encircling the tree trunk, the diameter at that point may be read directly.

16. Hypsometers. — The next commonest instrument for measuring trees is the hypsometer, an instrument for measuring heights; and since it is employed almost exclusively for measuring the heights of standing trees, the term has been defined by the committee on terminology * "an instrument for measuring heights — especially of trees."

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* These dimensions apply to the so-called 36-inch calipers. These are the most generally useful in the north-eastern United States. Calipers are also made with beams 20 inches long and with beams 54 inches long, to suit the needs of special cases or localities.

Hypsometers are of many styles and kinds, but they all depend upon the geometric principle of similar triangles, or upon the trigonometric principle of tangents. To illustrate these principles, only two or three of the many kinds of hypsometers will be described here.

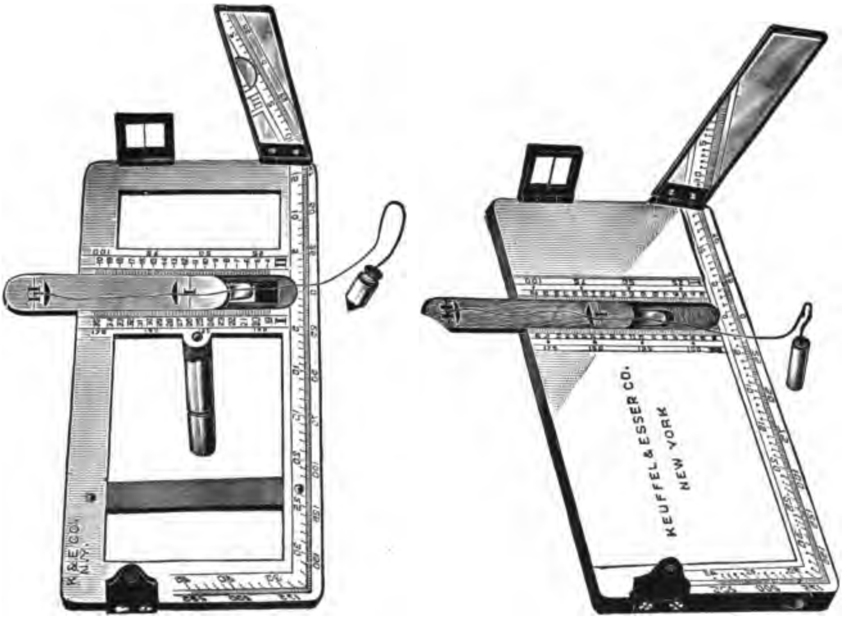

FIG. 5. The Faustmann Hypsometer.

(*a*) *Hypsometers Based on the Principle of Similar Triangles*

Faustmann. — This instrument, made originally in Germany, but also made in this country under patent rights, consists of a metal frame (or, in the cheaper models, a rectangular board), about 7 inches long and 3¼ inches wide. (See Fig. 5.) The following description of the instrument is reprinted from Bulletin 36, U. S. Dept. of Agriculture, Forest Service, the "Woodsman's Handbook," page 99:

"This instrument consists of a skeleton rectangular metal frame having two crossbars at one side of its longitudinal center, the frame and bars being in one piece. A slide, reversible end for end and having beveled edges, works in undercut grooves formed in the inner edges of the crossbars. This slide is provided at its ends with thumb notches and with transversely arranged index marks, designated I and II. A plumb line carrying a plummet is attached to the slide in the center of the index mark II. A retaining spring secured to the back of the frame and bearing against the inner face of the slide holds it in any position in which it may be set. The left-hand end bar of the frame is furnished with an eyepiece, and the right-hand end bar with an objective, these being made of metal and hinged so as to be folded down out of the way when the device is not in use. A long, narrow mirror, hinged to the frame at a point below the objective, is furnished to reflect a right-hand horizontal scale and a left-hand horizontal scale engraved upon the lower bar of the frame, and meeting at a zero point which is intersected by a line passing through the longitudinal center of the slide. The right-hand scale runs to 75 and the left-hand scale to 225, the latter scale extending upward on the left-hand end bar of the frame. The right-hand crossbar is provided with a vertical scale running upward from zero to 100, and continued on the left-hand crossbar with a scale running upward to 175. These scales are divided in fifths and numbered. The lines forming the scales are equally separated from each other and represent units of distance under any system of measurement that may be adopted. The handle of the device is attached to the left-hand crossbar.

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* See "Journal of Forestry," vol. XV, No. 1, 1917.

"To use the instrument, the observer measures the horizontal distance in feet, yards, or in any other desirable unit, from where he is to stand to the base of the tree. He then sets the slide by one or the other of its two index marks, which is brought into line with the graduation on the vertical scale corresponding to the measurement just secured. If the distance is less than 75, the slide should be set so that the upper end of the plumb line will take a position opposite the required number on the portion of the vertical scale on the right-hand crossbar. If the distance is more than 75, the slide should be pulled out and reversed end for end and adjusted until the index mark at its then lower end is brought opposite the required number on that portion of the vertical scale on the left-hand crossbar. The observer then looks through the eyepiece and objective and brings the hair of the latter into line with the top of the tree. The plumb line is allowed full play and crosses the left-hand horizontal scale. As soon as the plumb line is at rest the number which it crosses is read off in the mirror. This number indicates the height of the tree from the level of the observer's eye to its top. He then sights through the instrument to the base of the tree and reads the number crossed by the plumb line on the right-hand horizontal scale. This number indicates the distance from the level of the observer's eye to the base of the tree, and is added to the number before secured, which gives the total height of the tree. If the observer should be standing so that the level of his eye is below the base of the tree, he should first determine the height from the level of his eye to the top of the tree, then the height from the level of his eye to the base of the tree, and subtract the last result from the first, which gives the true height of the tree."

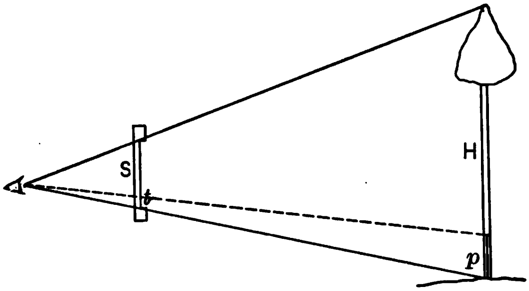

FIG. 6. Christen Hypsometer.

A very simple instrument which gives approximate results is the Christen Hypsometer, an instrument used in Switzerland and other European countries to some extent. It consists of a flat piece of metal with a notched edge of known length. The instrument is held lightly between the thumb and forefinger and allowed to assume a vertical position at such a distance from the eye of the observer that the image of the tree to be measured fits precisely into these notches. (See Fig. 6.) The point on the graduated scale, t, where the line of sight from the eye to the top of a pole of known length, standing against the tree, cuts it, gives the height of the tree, provided the relation between the length of the pole and the distance between the notches of the graduated scale is known, and the graduations placed accordingly. The principle is one of similar triangles. If $\frac{H}{p}$ is the ratio of the tree to the pole, and s = the length of the scale (*i.e.*, the distance between the notches on the instrument), and t = the part of the scale subtended by the image of the pole, then,

$$\frac{p}{H} = \frac{t}{s},$$

and if, with known values for p and s a value of H is assumed, the corresponding value of t may be computed and marked on the scale. Similarly, other values of H are assumed (usually at intervals of 5 feet, *e.g.*, 30, 35, 40, 45, 50, 55, etc.), and by applying the formula, the corresponding values for t are computed and marked on the scale.

(*b*) *Hypsometers based on the Principle of Tangents*

An example of the type of hypsometer operating on the principle of tangents is the Forest Service Grademeter, or Hypsometer. This instrument serves equally well to determine grades and heights. Combining as it does the ability to perform these two classes of work, so common in forest work, with a small compact form of light but strong construction, this instrument is decidedly useful to the forester. It consists of a circular metal box about 3¾ inches in diameter and ¾ inch thick. (See Fig. 7.)

A weighted dial on the inside, which is released by pressing a control-spring, shows by a printed scale the tangent of the angle at which the instrument is held, x 100. Or, in other words, the scale shows directly, in terms of percentage of the measured base-line, the elevation above the level of the eye, or the depression below the level of the eye. From these two readings the height of the tree is readily obtained.

The Goulier clinometer operates on exactly the same principle as the Forest Service Grademeter, and while extremely useful, is not of such compact, durable construction.

A hypsometer to give the greatest satisfaction in the field must combine lightness, strength, durability, ease of manipulation, and accuracy. Some of them sacrifice one or more of these qualities to obtain others. For example, the Christen hypsometer is light, strong, durable, and simple; there is nothing to get out of order; but the necessity for carrying about a pole of known length, together with the fact that it is a physical impossibility to read the scale very accurately makes this instrument of doubtful practicability. The Faustmann is capable of very accurate readings when the wind does not blow the weighted thread, but this fact, together with the frail construction, the liability of the mirror to breakage, and the fraying of the thread, makes it an instrument of limited usefulness. The Forest Service Grademeter, while not capable of such great accuracy as the Faustmann under favorable conditions, combines so many of the desirable features that it is perhaps the most generally useful of any of the instruments mentioned.

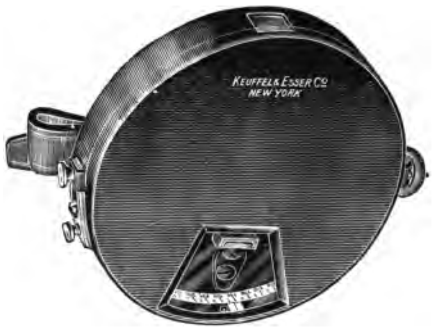

FIG. 7. — Forest Service Standard Hypsometer.

17. Scale Sticks. — Scale sticks are usually made of some tough, flexible wood, like hickory, and present no such variety of forms as hypsometers. While there is a choice offered in the style of ferrule which fits on the end of the stick, the common forms are flat rules, about 1½ inches wide, ¼ inch thick, and from 40 to 50 inches long. One edge is graduated to inches; the other edge to some little-used log length, as, for example, 20 feet. The two flat sides are graduated to show the contents in board feet for logs of standard length, the 12's, 14's, and 16's on one side, and the 8's, 10's, and 18's on the other side. Thus the scaler has conveniently arranged, all on the same side, the board foot values of the commoner log lengths, 12, 14, and 16. Some of the styles are shown in Fig. 3, page 23.

18. Increment Borers. — The increment borer is an instrument for determining the rate of growth in diameter of standing trees. It consists of a hollow augur, which when bored into the tree at right angles, extracts, by means of a removable plug called the "extractor," a core of wood, about a quarter-inch in diameter, on which the annual rings of growth show. Increment borers are made in several types, the commonest of which is the so-called Swedish increment borer; they come in various sizes, classified as to the length of the wood core which they are capable of extracting. They are extremely useful in obtaining reliable data as to diameter growth, and while not adapted for use in trees with a very hard wood, are nevertheless indispensable to the practical forester.

19. Dendrometers. — A dendrometer is an instrument combining height and diameter measurement, adapted to measuring diameters indirectly. Some of the simpler forms require no lenses, but most of them, if they pretend to any degree of accuracy, or applicability to a wide range of uses, employ telescope-tubes, with lenses of moderate magnifying power. A very elaborate, yet thoroughly practical form of dendrometer, is described in *Forestry Quarterly*, vol. XI (1913), page 467. The inventor of this instrument, Dr. J. F. Clark, claims that its use is justified in cruising very tall timber, or very valuable timber. Such instruments have no place in the rough cruising methods generally employed in extensive work, nor would they be economical in estimating the timber in a farm woodlot.

20. Biltmore Stick. — An instrument for measuring the diameters of trees which has come into quite general use among foresters in this country, especially in reconnaissance work and rapid cruising, is the Biltmore stick. So far as the authors know, this stick was first described in the *Forestry Quarterly*, in

1911.* It is defined as a graduated rule, usually of wood, the graduations of which indicate the diameter of the tree at the point measured, when the rule is held tangentially to the tree. It is so much lighter than a pair of calipers, and when used with care gives results so little less accurate, that for cruising, or measuring trees where diameters to the nearest inch-class are sufficient, this instrument can be recommended heartily. It must be remembered, however, that in the hands of careless men, very inaccurate results may be obtained. The Biltmore stick has been tested in field-work, and for a discussion of the results of this test, the reader is referred to the *Forestry Quarterly*, 1911.* It is possible to combine on one stick, of suitable size for a Biltmore rule, not only the graduations spoken of above, but also the values for a log rule, so that the stick serves not only to measure the diameter of standing trees, but also to scale logs. Or a hypsometer, based on the principle of the Christen Hypsometer, may be incorporated with the other uses of the stick. For a discussion of the mathematical principles on which this rule is constructed, and the errors to which it is liable, the reader is referred to the citation in the *Forestry Quarterly*, already mentioned, and to an article in the *Proceedings, Society of American Foresters.*†

The authors believe that the range of use for the Biltmore stick might well be extended and, in the hope that many cruisers will adopt it as a rapid and easy means of measuring tree-diameters, there is included in the Appendix a table of values for the Biltmore stick, suited to various arm-lengths.

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* Jackson, A. G.: "Biltmore Stick," Forestry Quarterly, IX, page 406.

† Bruce, D.: "Notes on the Biltmore Stick," Proc. Soc. Am. For., IX, page 46.

CHAPTER V

THE MEASUREMENT OF FELLED TREES

21. Introduction. — One of the chief objects of forest mensuration is the measurement of whole stands of trees, *i.e.*, timber cruising, or timber estimating. The only way to secure accuracy in this kind of work is to study, first, the form of the individual trees. Standing trees are hard to measure, but felled trees can be measured in detail — scaled to determine their contents in board feet, or measured in a sufficient number of places to calculate their cubic contents. As the basis for determining the contents of whole stands, therefore, the volumes of individual trees of different species, sizes, classes, and so forth, must first be known. These volumes, usually appearing in the form of volume tables (see Chapter VII), are determined from measurements made on hundreds — perhaps thousands — of felled trees, and since they are to be multiplied by large factors in arriving at the estimates for whole stands, it is of the utmost importance that the volume table values shall be as nearly faultless as possible for *average trees*. This can be accomplished only by making careful measurements on many felled trees, classified as to diameter and height, or merchantable length, or some other function which has a determining influence on the merchantable contents of a tree. (See Article 33.)

22. Selection of Trees for Measurement. — While the ideal method of procedure would be to inspect the stand for normal trees (*i.e.*, trees that are symmetrical, regular in form and development, sound, and free from excessive taper, crook, etc.), and to measure these normal trees in detail after felling them and dividing them into sections of even, standard length, such a course would obviously be very costly, both in time and money. A much cheaper way, and one which gives results nearly as satisfactory, is to follow the tree-felling crews in the woods, where a lumbering operation is in progress, and as they fell the trees, make the necessary measurements. For example, before the tree is felled, it can be inspected and judged for normality, and its breast-high diameter measured. As soon as it has been felled and cut into logs (and before these have been moved from their relative positions), all the measurements necessary can be made. (See Article 23.) To do this requires some little speed and agility in escaping the falling trees, but with practice, the work can be carried on without risk. No time is lost, no money need be spent for labor, and the slight inconvenience of having the sections made at different heights above the ground is more than offset by the large number of trees that can be measured.

23. Measurements made on a Felled Tree. — After felling a tree, it is usually trimmed of all branches and stubs to a height which represents the limit of merchantability, and cut into logs of standard lengths at the discretion of the boss of the crew. The following measurements are then recorded on forms prepared in advance, to save time:

(1) Diameter breast-high, in inches (taken before felling).
(2) Average height of stump, in feet and tenths.
(3) Length and diameter of each section (log).
(4) Length of top in feet and tenths.
(5) Clear length (stump to first stub or branch).
(6) Used length (= sum of values in (3)).
(7) Merchantable length.
(8) Length of crown (from first green limb to top).*
(9) Width of crown.*
(10) Total height (sum of 2, 3 and 4).

In addition to the above data, space is provided on the blank forms for the entry of the species, the locality, the date, the names of the men composing the crew, and any other information that would be useful. If mill scale studies are to be made on the same trees, each tree receives a number, and each log the same number and a letter, so that the logs can be identified when they reach the mill. For example, a certain tree, as it is felled, receives a consecutive number; this number is written on the stump with a crayon. The first log is then marked with the same number, followed with a dash and the letter "*a*" (*e.g.*, 117–*a*). The second log receives the tree-number followed by a dash and the letter "*b*" (*e.g.*, 117–*b*). In this way, each log can be identified, and it can be referred to the proper tree. Later, when the logs are sawed at the mill, the exact product of each log in sawed lumber can be measured and recorded, and in this way figures obtained which serve as a check not only on the scaling as done in the woods, but also on the volume tables which have been constructed from trees in the same locality, if such volume tables exist. A sample form, suitable for recording all the above data, is shown in the Appendix, page 261.

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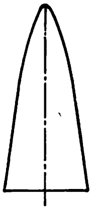
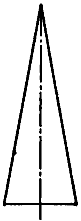
* The 8th and 9th measurements are not always taken. They are useful if growth studies are also to be made on the same trees.

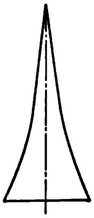
A word of explanation is needed with reference to measurement number 7 — merchantable length. It not infrequently happens that the lumbermen, because of certain restrictions in the trade, cannot use all of the merchantable portion of a tree. In other words, there may remain in the tops certain material which, under conditions permitting closer utilization, would be considered merchantable. It is customary to include this extra length, if there be any, under measurement number 7.

24. Application of Log Rules, or Mathematical Formulæ. — If only sound, normal trees have been measured, scaling need not be done in the woods, but it can be done in the office later. It has been pointed out in Article 13 that log rules show the *estimated contents of sound logs* which are reasonably straight and free from excessive taper. Therefore the computations for board-foot contents can be made directly from the data in the field note-books. Similarly, the cubic contents of the several sections of a felled tree can be computed by the application of certain formulæ which will now be discussed.

25. The Forms of Trees in General. — Under normal conditions a tree grows in height and diameter simultaneously; to be sure, the height-growth takes place much more rapidly than the diameter-growth, but the rate of each kind of growth follows certain rather well-defined laws, modified more or less by the differences in the seasons and the circumstances under which the tree grows. The product of growth in diameter and height is a solid which resembles certain geometric solids for which there are mathematical formulæ which enable one to calculate the cubic contents when certain dimensions are known. These solids are all cone-like, — *i.e.*, they taper as they ascend from the base, and finally come to a point (the growing tip of the tree). If the bole of the tree has a tendency to fill out in the middle and upper portions becoming more nearly cylindrical, it may approach very closely the geometric solid known as the paraboloid, because it can be conceived of as generated by the revolution of a parabola about its central axis. If, on the other hand, the tree has a spreading root-system, and there is considerable of a flare at the butt, so that it tapers very rapidly at the start, but becomes more and more like a cone as the top is approached, then the form will resemble that of a Neilian paraboloid, or Neiloid, which can be conceived of as generated by a curve of the third degree about its central axis.* Midway between these two forms is the true cone, which has a perfectly regular taper, and can be conceived of as generated by the revolution of a straight line


PARABOLOID
FIG. 8.


CONE
FIG. 9.


NEILOID
FIG. 10.

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* Expressed in terms of analytic geometry, the equations for the curves which generate these solids are as follows:

Parabola: $y^2 = 2\,mx$.
Neilian Parabola: $y^2 = 2\,mx^3$.
Cone: $y^2 = 2\,mx^2$.

In each case, m = an independent variable, called the *parameter*. See standard texts on mathematics, such as Woods and Bailey: "Analytic Geometry and Calculus," Boston, Ginn and Co., 1917.

about a central axis.* It is, therefore, possible to recognize three type forms which the stems of trees resemble, and these are shown in Figs. 8, 9, and 10 on page 43.

The formulæ for expressing the cubic contents of these solids are derived by methods of geometry or by integral calculus, and are presented here without proof.†

Formulæ for Contents of Geometric Solids

In each case:

H = height,
B = base (lower); b = base (upper).‡
$B_{\frac{1}{2}}$ = base taken at half the height.
$B_{\frac{1}{3}}$ = base taken at one-third the distance up from lower base.
V = volume.

1. Cone $$V = B \times \frac{H}{3}. \tag{1}$$

2. Paraboloid $$V = B \times \frac{H}{2}. \tag{2}$$

3. Neiloid $$V = B \times \frac{H}{4}. \tag{3}$$

4. Frustum of cone $$V = (B + b + \sqrt{Bb})\frac{H}{3} \tag{4}$$

and $$V = (3\,B_{\frac{1}{3}} + b)\frac{H}{4}. \tag{5}$$

5. Frustum of paraboloid

$$V = (B + b)\frac{H}{2} \tag{6}$$

and $$V = B_{\frac{1}{2}} \times H. \tag{7}$$

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* Perhaps an easier way to conceive of this is to say that a right-angled triangle revolves on its axis, the axis in this case being the longer side opposite the hypotenuse.

† Geometric proofs for these formulæ are shown in Baur's "Holzmesskunde" (Berlin, 1891), pages 46–65. Proofs by integral calculus are shown in Müller's "Lehrbuch der Holzmesskunde" (Leipzig, 1899), pages 9–15, and in other standard text-books on the subject.

‡ The area of the base is expressed in terms of square feet. To facilitate the calculations tables of basal areas have been constructed, showing for any diameter *in inches*, the corresponding area in *square feet*. See Appendix, page 231.

6. Frustum of Neiloid

$$V = (B + 4B_{\frac{1}{2}} + b)\frac{H}{6}. \qquad (8)$$

By taking advantage of the formulæ for *frustums* of the solids mentioned, it will be seen that the tree, instead of being considered as a whole, may be considered as composed of several parts, or sections (stump, logs, and top), and in this manner the contents can be computed very accurately. For example, the first or butt log may include some of the root swelling at the base of the tree, and, therefore, resemble closely the frustum of a neiloid; the second log may have a very even taper, and the form of it would, therefore, be the frustum of a cone; the third log of a three-log tree will very frequently resemble the frustum of a paraboloid; while the top may resemble either a cone or a paraboloid in form, depending on the rate of taper. Thus, if we have the formulæ for the frustums of these solids, we are enabled to apply the appropriate formula for each separate section of the tree and by adding all together obtain the total volume quite accurately — much more so, in fact, than could be done by applying a single formula. The formulæ included in the foregoing paragraph are merely a few of the more useful of the complete list, which numbers a great many more. Experience has shown that for most trees, the formula for the frustum of a paraboloid applied to the logs, and the formula for a cone applied to the top, will give very satisfactory results. If any one of the logs is very *obviously* of a different form, its volume may be found by applying the most appropriate formula. It should also be stated that the stump, being short, is usually considered as a cylinder. Although this introduces a slight error, it is negligible, especially when it is remembered that the stump is almost always but a small part of the total volume of the tree, and is not merchantable. The principal reason for including it in the computations is to obtain, as nearly as may be, the volume of the *entire* stem — a very important consideration in dealing with the subject of growth, or increment (See Chaper X.)

A formula which will give the volume of the entire stem of a tree is often a great convenience, especially if approximate results will fulfil the purpose, or if time is lacking to make a detailed computation of the contents by sections. Two formulæ are herewith presented, which, with a measurement made in one additional place besides the height and base, will give very fair results. They are, in fact, much more reliable than formulæ number 1, 2 or 3 (page 44), because most trees are not quite true to form, either of a cone, or a paraboloid, or a neiloid, but are intermediate; and the measurement of the diameter in another critical point, together with a measurement of the base and the total height, enables us to compute the volume with considerable accuracy. These two formulæ are as follows:

Schiffel's formula: $V = (\frac{1}{6}B + \frac{2}{3}b_{\frac{1}{2}}) \times H.$ (9)*

Pressler's formula: $V = \frac{2}{3}B \times H_{\frac{1}{2}d}$ (10)*

It will be noticed that Schiffel's formula is merely Formula No. 8, in which the upper base, *b*, has become a point (the tip of the tree), and hence, equal to 0. It therefore disappears from the formula. This formula requires that a diameter measurement be taken at a point midway between the base of the tree and its extreme tip. This can be done with any degree of accuracy desired, and either outside bark, or inside bark, on a felled tree; on a standing tree, the approximate diameter, outside bark, can be gotten by the aid of a dendrometer (see Article 19). Pressler's formula requires that a measurement of the height be made at that point on the stem where its diameter is just one-half that of the base. This can be done very accurately on a felled tree, but in the case of a standing tree, it must, of course, be obtained by the aid of a dendrometer. Pressler's formula is a very ingenious one, and it can be proved to be absolutely correct in the case of a tree whose form is that of a cone or a paraboloid. It is not quite correct in the case of a tree whose form is that of a neiloid, but the error, even in this case is less than one per cent, so that the formula is an extremely useful one, since the vast majority of trees will fall, in form, between a paraboloid and a neiloid.

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* B = lower base; $b_{\frac{1}{2}}$ = base taken at one-half the height; H = height; $H_{\frac{1}{2}d}$ = height at which the diameter is one-half that at the base.

26. Xylometric Methods. — In the case of parts of a tree which are very irregular, as is the case with branches, crotches, and deformed parts the only way to obtain the volume with any degree of accuracy is to plunge the part to be measured in a tank of water, and measure the volume of water displaced. This method is resorted to only under exceptional conditions, or where very accurate figures are required. It is not a method of common practice. One instance of its application, however, may serve to show how it can be made very useful. It is a well-known fact that the amount of solid wood in a cord of stacked wood varies considerably according to several factors (see Appendix, page 227). About the only way in which irregular pieces of wood of this kind can be measured accurately is by measuring the amount of water they displace. Several exhaustive studies of cordwood have been made, with the result that it has been found that the amount of solid wood in a stacked cord varies all the way from 73 cubic feet to 92 cubic feet. The significance of these figures to manufacturers and buyers of pulpwood is immediately apparent.*

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* See Zon, R.: "Factors Influencing the Volume of Solid Wood in the Cord," Forest Quarterly, vol. I, pages 126–133.

CHAPTER VI

THE MEASUREMENT OF STANDING TREES

STANDING trees can be measured to obtain diameter, height, and volume. Only the first of these three can be obtained by direct measurement; the other two quantities can be gotten by indirect methods, the degree of error depending on the refinement and accuracy of the instruments employed, and the care with which they are operated by the users.

27. Measurement of Diameter. — Diameter can be measured by the tree calipers, by the Biltmore stick, or by the circumference-tape. (See Chapter IV.) For trees of small and medium diameters, — *e.g.*, up to 36 inches, — the calipers or the Biltmore stick are to be preferred; for trees of large diameter, such as those growing in the forests of the Pacific slope, the circumference-tape is the only practicable means of measurement. This is because calipers of a size sufficient to measure these very large trees would be too cumbersome, and the Biltmore stick, although it can be constructed, theoretically, for trees of any size, cannot be read closely when applied to trees of very large size.*

Foresters measure the diameter of standing trees at a height of four feet, six inches from the ground, a point spoken of as "breast-height." (Commonly abbreviated to "d.b.h.") If the tree stands upon level ground the determination of breast-height presents no difficulty; if, however, the tree stands upon a slope, or if the ground at the base of the tree is very uneven, the determination of breast-height is a matter for the exercise of some care. The rule, under such circumstances, is to stand in such a position that the feet are upon a contour line running through the center of the tree. This secures an average measurement and saves the time and labor of taking the mean of two measurements — one made from the upper side, and one from the lower side of the tree.

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* The limit of accuracy for the Biltmore stick is about 42 inches. See Jackson, A. G.: "The Biltmore Stick," Forestry Quarterly, IX, page 406.

Nearly all trees are more or less eccentric in cross-section; this means that in careful work the calipers should be applied at more than one position (all at breast-height, of course). The easiest and quickest way to secure an average measurement of breast-height diameter is as follows: in applying the calipers to a tree, the jaws are opened, the caliper placed with the graduated beam tangent to the tree, and then the jaws are pressed together until they both touch the tree. If the calipers are revolved about, as this pressure is exerted, the sense of touch will tell when the ***minimum*** diameter has been reached. This can then be read from the graduated beam, and carried mentally until the ***maximum*** diameter has been measured, which, ***in*** 9 ***times out of*** 10, ***will be found at right angles to the first position.*** The mean of these two readings can usually be made mentally, and represents the average diameter of the tree. This quantity is the one that should be recorded, rather than a diameter obtained by a single reading of the calipers, applied at random. In some kinds of work, requiring extreme accuracy, for the purpose of making future comparisons, both the maximum and the minimum diameters are recorded. (See Article 75, Permanent sample plots.)

Sources of error in measuring diameter are: (1) calipers not adjusted correctly, (2) calipers not held at breast-height, (3) calipers not held at right angles to the stem of the tree, (4) calipers held so as to include some abnormality of form of the tree. In order to guard against these errors, the calipers should be inspected at frequent intervals, and corrected by the adjustment-screws (see Article 15) if they need it. Elimination of errors number 2 and number 3 can be obtained only by exercising constant care. Error number 4 is not always easy to avoid; if it is necessary to measure a tree with an abnormal form just at breast-height, the mean of two readings, one above and one below the deformity, should be taken. It is far better, however, to measure only normal trees, unless the character of the work requires that *all* trees be measured. Trees that fork should be measured as two or more trees, even if the calipers have to be held slightly above the regulation 4½ feet above ground, for in utilizing such trees, the lumbermen would probably "butt off" the forked portion. Provision for other unusual abnormalities or conditions can be made at the discretion of the man in charge of the measurement.

28. Measurement of Height. — The measurement of the height of standing trees is attended with no special difficulties. The chief sources of error are: (1) incorrect measurement of the base-line on sloping ground, (2) no allowance for the departure of the stem from a perpendicular position, (3) failure to make the observations on the very bottom and very top of the tree, (4) lack of proper care in the use of the hypsometer, leading to inaccurate readings.

These errors can be eliminated very largely by exercising care in the manipulation of the hypsometer. The base-line should, of course, be measured horizontally, and under no circumstances along the surface of sloping ground. (See Article 3, page 6.) If a tree leans, the observer with the hypsometer should take up his position at right angles to the direction of inclination (*e.g.*, if a tree leans to the north, make observations from a position either due east, or due west). It is better, however, to measure none but straight trees, for leaning trees are too apt to be abnormal in some respect. The third error is of frequent occurrence in dense stands, where the foliage may very easily obscure the view. Often, the crowns of trees in a dense stand are difficult to distinguish, one from another, and the greatest care must be taken to avoid mistakes of this character. The temptation to work constantly with a base-line of exactly 100 feet, thereby saving computations, should be resisted, for very often a little time spent in finding a place from which a clear view of both the top and the bottom can be obtained, will be more than offset by the danger of making doubtful observations at some arbitrary point chosen simply because it would obviate the necessity for mathematical computations. It is easier to measure a base-line through masses of intervening foliage and under-growth than it is to make observations through similar obstructions. Error number 4 — lack of care — is sometimes more difficult of elimination in the presence of strong winds. Some types of hypsometers are very difficult to operate accurately if a strong wind is blowing, and all that can be done is to wait for a quiet day. A windless day has the further advantage that the trees themselves are not swaying, and it is then much easier to obtain accurate readings with the hypsometer.

29. Measurement of Volume. — The volume of standing trees can be obtained approximately by any one of five methods:

(1) Measure the diameter breast-high, and either the total height, the merchantable height, or the number of logs of standard length that the tree will yield, and then refer to the appropriate form of volume table for trees of the same locality. (See Chapter VII.)

(2) Measure the diameter at the base of the merchantable stem, the total height, and the diameter at one-half the height (this is done by the aid of a dendrometer). Then apply Schiffel's formula. (See Article 25.)

(3) Measure the diameter at the base of the merchantable stem, the height at which the diameter is exactly one-half of this value ($H_{\frac{1}{2}d}$. See Article 25), and then apply Pressler's formula.

(4) Measure the diameter at breast-height, the total height, and then apply the method of form factors. (See Article 30.)

(5) Measure the diameter at breast-height and estimate by the eye the number and top diameters of logs of standard length, scaling each log separately by any desired log rule. (See Article 44.)

30. Form Factors. — A form factor is the ratio, expressed decimally, between the volume of a tree and the volume of a geometric solid (usually a cylinder) of equal height and basal area. There are several kinds of form factors, depending on how much of the tree is included in making the volume calculations, and at what point the diameter of the tree is measured. In this country, it is generally understood that the diameter of the tree is measured at breast-height, and that the volume of the stem, exclusive of the branches, is used in comparison with the volume of a cylinder. This is called the "breast-height stem form factor," or simply, the form factor. If, however, the volume is understood to include not only stem, but branches, it is called the tree form factor; if only the merchantable portion of the stem is included, then it is called the merchantable form factor. In recent years other kinds of form factors have been devised, as, for example, the so-called frustum form factor, comparing the board-foot contents of trees, within certain merchantable limits, with the board-foot contents of ideal frustums of cones, in which the taper is regular.*

If the time ever comes when the cubic foot becomes a common unit of measure in this country, it is quite probable that form factors will be more generally used here. For the present, the use of form factors will doubtless be confined rather closely to theoretical investigations. The very fact that there is no constant ratio between board feet and cubic feet makes it difficult to use form factors in any practical way.

31. Use of Form Factors. — Once a complete table of form factors has been constructed for trees of different species, and growing under certain stated conditions, the computation of the cubic-foot contents, either of single trees, or of whole stands, becomes a relatively simple matter. The formula for finding the contents of a tree by the method of form factors is

$$V = B \times H \times FF$$

in which V = volume, B = basal area in square feet (see Appendix, page 231) and FF = the form factor. In the case of whole stands, the total basal area of all the trees in the stand is used, and this quantity, multiplied by the average height and the forest form factor (*i.e.*, the average form factor for the whole stand) gives the contents of the stand. This method will yield satisfactory results only in the case of pure, even-aged stands of great regularity. The saving in labor and time is, of course, very considerable, but at the present time there is a lack of adequate tables of form factors, and the conditions in the forest are so rarely favorable to the use of the method in this country, that it is practically never used.

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* See Forestry Quarterly, vol. X, pages 215–221. Bruce, D.: "A New Method of Constructing Volume Tables."

Other kinds of form factors, depending on where the base is measured, are: (1) the absolute form factor, in which the base is measured level with the ground, and (2) the normal form factor, in which the base is measured at a height above the ground bearing a certain ratio to the total height of the tree. These form factors are used chiefly in Europe, in theoretical work, and are practically unknown in this country.

CHAPTER VII

VOLUME TABLES

32. Definition and Uses of Volume Tables. — A volume table is a tabular statement showing for a given species the average contents of trees of different sizes. Volume tables may be made for any desired unit of volume, as, for example, board feet, cords, standards, cubic feet, ties, and so forth; the most commonly employed units are board feet and cubic feet. With proper converting factors it is possible to transform volume tables in cubic feet to volume tables expressed in terms of cords, standards, etc. Volume tables are used chiefly in connection with timber estimating. After the tally of trees is complete, the appropriate volume tables are applied to obtain the estimate in terms of the desired unit of measure. Used with due consideration for the limits within which they will apply, accurate volume tables may be relied upon when they are applied to a large number of trees; but it is not to be expected, from the manner of their construction, that they will apply to individual trees. (See Article 38.)

33. Classification of Volume Tables. — According to the manner in which the trees are classified, there are several kinds of volume tables. The commonest in general use are as follows:

(1) *Volume Tables Based on Diameter Only*

In this form of table the trees are classified by diameter breast-high only. No account is taken of the height or the form of the tree; hence these tables are of little practical use unless they are applied to trees of form and development similar in all respects to the trees from which the tables were constructed. This limits the use of these tables to restricted localities, and unless there is a prospect of using them locally, it scarcely pays to construct such volume tables. The locality in which the table was constructed, the limits within which it applies (especially the minimum diameter in the tops, and the average height of stumps), the log rule used in scaling, and the average dimensions of the lumber sawed from the logs, are also important pieces of information which should be included in these, as in all other volume tables. (See Article 23.) These data have a special importance, however, in the case of volume tables of this class, and tables lacking them should never be employed.

(2) *Volume Tables Based on Diameter and Total Height*

It has been pointed out in Article 31, where form factors were discussed, that height and diameter are both important functions of the volume of a tree. It needs but a moment's reflection to perceive that of two trees of equal diameter and of similar form, but of different total height, the taller tree will have the larger volume. This is not only true of the cubic contents, but is even more emphatically true of the merchantable or board-foot contents; for the taller tree has less taper, and will yield more logs, each one slightly larger in diameter than the corresponding log of the shorter tree, thus producing a total of board feet considerably in excess of the product of the shorter tree. In volume tables that show the average contents of trees classified both by diameter *and height,* it is therefore possible to express the contents much more accurately. Moreover, such tables are susceptible of a wider application, because the heights of trees, even within a comparatively restricted geographical range, will show marked differences, reflecting the differences in *quality of site.* (See Chapter XI.) In constructing tables of this kind it is customary to classify the trees, as to height, in 10-foot classes. In other words, all trees 56 feet and over, up to 65 feet, would be included in the 60-foot class; all trees from 66 feet to 75 feet inclusive would be thrown into the 70-foot class, and so forth. A greater degree of refinement is scarcely needed. An example of this form of volume table is shown in the Appendix, page 232.

(3) *Volume Tables Based on Diameter and Merchantable Length*

If it is true that the total height is such an important factor in determining the volume of a tree, then the ***merchantable length*** is even more important. By adopting this classification of trees the greatest degree of accuracy in volume table construction can be secured. Since common usage calls for logs in multiples of two feet (*i.e.*, 8-foot logs, 10-foot logs, 12-foot logs, etc.), it is necessary to recognize merchantable heights in the same way, in order to meet any possible combination of log-lengths. This means that a volume table constructed according to this plan must have as many columns as will be necessary to provide for all the possible merchantable lengths — often as many as 30 or 40 columns. Such a table would be very complicated and unwieldy; would occupy too much space; and would be open to the objection that, in order to warrant its use, the merchantable heights of the trees estimated must be judged with great precision, — to be exact, within two feet, — a degree of precision which in fact calls for the constant use of hypsometers. This makes the work of cruising proceed very slowly and laboriously, and it is a question whether the time and money spent in this meticulous manner can be justified by the results. After all, a timber cruise is only an *estimate*, and there are limits beyond which it will not pay to go. Tables of this form, therefore, are rare; and the occasion for their use is very unusual. Under conditions that demand some attention to the merchantable length of the trees in a cruising operation, it will be found that a classification of trees into groups by the ***number of logs of standard length*** will meet all the requirements, and the use of tables of this kind is not only practicable, but is often the most satisfactory when considering the two desirable features of efficient timber estimating, namely, accuracy and reasonable cost. Tables of this form will now be discussed.

(4) *Volume Tables Based on Diameter and Number of Logs of Standard Length*

The standard log usually selected for tables of this form is the sixteen-foot log. This length is, perhaps, the one most commonly used, and it is customary to recognize half-lengths (8 feet) in the preparation of the volume tables. This provides for a considerable degree of accuracy and at the same time the table is of such proportions that it can be printed on a single page of a hand-book or field-book. Moreover, a skillful cruiser needs no instrument for measuring height, — his eye can be trained to estimate log-lengths of this size with sufficient accuracy to make tables of this form practicable. After a little practice in judging merchantable lengths to the nearest 8 feet, the work proceeds with great ease and rapidity. A further point to be considered is this: the blank form in the cruising note-book is not unduly wide, and the tallying process can be carried on easily and quickly. All things considered, it seems safe to say that when this method is followed, *i.e.*, trees estimated and tallied according to log-lengths, recognizing units as small as 8 feet, the greatest degree of accuracy consistent with economy of time and labor in the work of cruising, can be obtained. Tables prepared according to this form are becoming more and more common, and they have met with almost universal approval by foresters and cruisers who are in the habit of doing careful, accurate work.* A sample of this form of volume table is presented in the Appendix, page 233.

(5) *Volume Tables Based on Diameter and Tree-class*

For some kinds of work, particularly the estimating of cordwood, pulp-wood, or wood intended for a form of use where *actual cubic contents* is of more consequence than the *form* of the pieces, volume tables prepared for trees of different diameters

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*** As further evidence of the usefulness of tables in this form, it may be stated that the U. S. Forest Service is now, and has been, for some time past, preparing and publishing all its tables on this basis, using the 16-foot log as the standard, and recognizing half-logs (8-foot lengths) in the tables.**

and *crown classes* are useful. For example: A tree of large diameter, growing in the open, or in an uncrowded stand, may produce a very large, round-headed crown, composed of many branches which are perfectly good as fuel, but worthless as lumber. Such a tree compared with one of equal diameter, but smaller crown, would yield a much greater quantity of cordwood. It will take a special form of volume table to show this difference in volume. Again, certain species of trees adapted to growing both in dense stands and in uncrowded or open stands will display the greatest difference in form, and consequently a difference in volume, depending on the situation in which they are growing. Hard maple, grown in a dense stand, produces a long stem topped by a relatively small crown; in the open it often attains a large diameter and good height, but the stem almost invariably divides again and again, until a large, round-headed crown is the result. This tree would yield perhaps four or five cords of wood, but practically no saw-timber. Under such conditions, the irregularity of tree form makes the use of the ordinary volume table impossible; but if volume tables based on diameter and *tree form* are available, the work of estimating such timber can be done with considerable confidence.

The classes of trees recognized in making tables of this kind are usually based on crown development. A convenient form of classification is as follows:

CLASS A. Trees growing in the open, with large, spreading crowns, occupying from 75 to 90 per cent or more of the total height.
(Large oaks, maples, and hickories growing in old pastures are good examples of this class of tree.)

CLASS B. Trees in uncrowded stands, with irregular, forked, and many-branched stems, the crown occupying from 50 to 75 per cent of the total height.
(Maples in an old sugar bush, or irregular trees of inferior form left after culling the best merchantable trees in a stand, are common examples of this class of tree.)

CLASS C. Trees in crowded stands, with crowns occupying less than 20 per cent of the total height, and with irregular, deformed, crooked stems.
(Trees badly oppressed, or totally suppressed, as a result of insufficient light and growing space, are examples of this class of tree.)

It will be noticed that this classification takes no account of those trees the crowns of which occupy from 20 to 50 per cent of the total height. Trees answering this description are more than likely to be *normal* in form, and therefore the ordinary form of volume table will be applicable, providing the trees are straight enough to yield saw-logs.

Volume tables of this kind are sometimes very useful, but are not common, since they are extremely limited in their range of usefulness. They are generally prepared for restricted localities, and are not applicable to stands outside those localities. They apply to classes of trees which are, strictly speaking, *abnormal*, and since the ordinary volume table should be constructed from *normal* trees only (see Article 35), these tables are what might be termed "exceptional."

34. Kinds of Trees from which Volume Tables are Constructed. — By definition (Article 32), volume tables show the *average* contents of trees of different sizes. It is therefore necessary to exercise great care in the selection of trees for measurement, as the basis for constructing the table, and to use only those trees that are found to be normal and representative of the average for the locality. This means that trees of unusual proportions must be excluded; it means that no crooked, diseased, forked, or broken-topped trees shall be included; it means, in short, that practically all trees described under Classes A, B, and C in the preceding article, shall be excluded. For the very fact that these trees have had to be classified as to form and crown development means that they are not *normal*, *average* trees. Grown under normal conditions in the forest, a tree will usually produce one stem, which is rarely absolutely straight, and practically never of perfect geometric form; nevertheless, the average tree of a given species will approach rather closely a certain, definite form which is quite constant for the species. This has been proved conclusively by many thousands of measurements on trees grown under favorable silvicultural conditions. It may not always be possible to tell by a superficial inspection whether or not a tree is of average, normal form; but errors in judgment of this kind can generally be detected when the trees have been properly classified preparatory to constructing the tables. The methods usually followed are described in the next Article.

35. Methods of Constructing Volume Tables. — (*a*) *In the Field.* — If the cost of the work is to be kept within reasonable limits, it is impossible to fell trees for the special purpose of volume table construction. Moreover, such a course of action would be unnecessarily wasteful, unless the felled trees could be utilized promptly. The usual custom is to follow the tree-felling crews of a lumbering operation, and, as pointed out in Article 22, use the trees that are cut by these crews, always observing, before the tree is cut down, whether or not it appears to be normal, and obtaining the diameter breast-high measurement while it is yet standing.* After the tree is felled and cut into sections the measurements described in Article 23 may be recorded in the field book, together with such additional notes and comments as the needs of the work dictate. The computations mentioned in Article 24 are now made, not in the field where such work is carried on at a disadvantage, but in the office, where computing instruments make the work easy. This work will now be described.

(*b*) *In the Office.* — If the field notes have been taken accurately and the descriptions of the trees made with care, the work of computing the contents of the trees measured in the field progresses smoothly and rapidly. First, all the trees of the same diameter-class and the same height-class are grouped together; in doing this work, fractions of an inch in diameter are considered as going to the nearest whole inch *above* if the fraction is 0.6 or more, and to the nearest whole inch *below* if the fraction is 0.5 or less. The heights are classified as explained in Article 33. The several logs of each tree of a given class are then scaled by some acceptable log rule, and the total contents of each tree obtained by adding together the contents of the several logs. When this has been done for all the trees of a specified inch-class (*i.e.*, diameter-class) the values are averaged together to determine the *mean* value for all trees of that particular class.

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* It is possible to obtain the diameter breast-high of a felled tree, but the measurement is not made so easily, and a liability of error always exists.

The following tabulated arrangement of the data is suggested as being easy to work with, and it will further serve to enlighten the text:

Average contents of trees of {60-foot height-class
14-inch diameter-class

Tree No.	27	85	192	215	218	507	etc.
D.b.h. (inches)	13.7	14.2	14.5	13.6	14.1	14.3	etc.
Height (feet)	56.3	61.4	62.1	60.1	59.8	64.7	etc.

Board feet by Scribner Rule.

First log	55	55	59	55	59	69	
Second log	32	35	40	35	40	30	
Third log	14	18	18	12	18	18	
Total	101	108	117	102	117	117	

Average diameter, breast-high	14.07	inches
Average height	60.7	feet
Average board-foot contents	110	board feet

While there is naturally some difference between the values for the several trees, the extremes — 101 and 117 — are not very far from the average, 110. This figure may therefore be accepted. If, however, any large discrepancies had appeared, it would have been wise to go over the figures again, to see if any mistakes had been made. If the work were found correct, then those trees which depart very widely from the general average should be eliminated from the calculations, on the ground that they are not normal.

After having averaged together the values for each class of tree, the easiest and quickest way in which to construct a table is to employ the graphic method.* For much of the work in forestry, graphic methods are by far the best to employ because the dependent variable quantities, like height, volume, diameter, rate per cent of growth, and so forth, are practically always made functions of age — *i.e.*, *time*, which is the independent variable quantity. Sometimes diameter, which is closely associated with, and related to, age is made the independent variable, but even in such cases the graphic method can usually be made to apply. In the case under discussion at present, the contents in board feet (the dependent variable) of all the trees of a particular height-class can be plotted on diameter breast-high (the independent variable) and a curve can then be drawn which represents the relation of board-foot contents to diameter. The several points should be plotted on cross-section paper, and a smooth curve should be drawn through them. The same procedure is followed for trees of the next height-class, and continued until the data for all the height-classes have been plotted. The curves should then be compared and harmonized,† so that the values for the several height-classes progress smoothly and evenly. From these curves, the appropriate values may then be read off and tabulated, showing for each inch-class in diameter the corresponding volume in board feet, each height-class being arranged in a vertical column by itself. See sample volume tables in the Appendix, pages 232 and 233.

36. The Method by Taper Curves. — If tables are prepared to show for different species and height-classes of trees the average diameter measurements of the stems at specified heights above the ground (inside bark) a means is thereby afforded for obtaining the contents of the trees *by any desired log rule*, since the process is, in effect, a process of scaling on paper the logs of normal, average trees. Such tables are called form tables, or taper tables, and are constructed from taper curves, which in turn have been drawn from the measurements of many normal, felled trees. Good examples of taper tables may be found in several of the recent Department of Agriculture Bulletins which deal with the form and contents of commercial species of trees.* The diameter measurements are usually made at stated intervals up the stem of the tree, and are corrected to show diameter *inside bark*, so that scaling can be done properly. The intervals above ground are generally as follows: 1 foot, 2 feet, 3, 4, 4.5 (breast-height), 9.15, 17.3, 25.45, 33.6 feet, and so forth, progressing by increments of 8.15 feet. In this way allowance is made for a 1-foot stump, above which are half-logs of 8.15 feet, and full logs of 16.3 feet. (The extra 0.15 foot and 0.3 foot are the allowances for trimming.) To make a volume table for any given species of tree from taper tables, the several logs, as shown by the diameter values in the tables, are scaled to any desired merchantable limit in the tops and by any preferred log rule. In this way, it is possible not only to choose one's own limits of merchantability, but to select one's own log rule; these advantages are obvious, since it may be necessary to vary the merchantable limits in order to conform to local utilization practices, or to use a particular log rule, which is in favor locally. More and more of these taper tables are being published, and in time there will be enough of them to make their general use quite practicable. They are by far the most logical way in which to attack the problem of preparing serviceable volume tables.

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* For an admirable discussion of all sorts of graphic presentation of data, see Brinton, W. C.: "Graphic Methods," New York, 1914, The Engineering Magazine Co.

† This can be done to best advantage by drawing all the curves on one sheet of paper.

Taper tables, or form tables, are constructed from a set of harmonized curves, each set being drawn from the data secured by measuring many trees of a given height-class, from which the average dimensions are calculated.

37. Checking Volume Tables by Mill Scale Studies. — It is often desirable, although not always possible, to check a volume table by studies at the saw-mill, which include, first, scaling logs which have been marked serially in the woods (see Article 23), and secondly, following them through the mill to see what they actually produce. If this work can be done for about one hundred entire trees, of different size-classes, a fairly reliable check on the volume table is obtained. It is especially desirable that this work be done in cases where the trees are suspected of hidden defect, or where they run very irregular in form.

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* See especially U. S. Dept. Agr. Bul. 285, "The Northern Hardwood Forest" (1915), Tables 43, 44, 45 and 46. Others are listed on page 237 of the Appendix.

38. Application of Volume Tables. — Now that the method of constructing volume tables has been explained, it will be understood why any one individual tree can hardly be expected to yield the exact amount of lumber assigned to it by the appropriate value in the volume table. The chances are that not more than one tree out of 100 trees of the same diameter- and height-class would show a *scaled volume* the same as the volume table value. If it is remembered, further, that a tree with a merchantable length of, say 48 feet, can be scaled as three 16-foot logs, or four 12-foot logs, or four 10-foot logs and one 8-foot log, and so forth, it will be clear that the chances for an agreement between the scaled value and the volume table value are still more remote, because the results of the scale depend on the way in which the tree is divided into logs. But when the volume table values are applied to a large number of trees, these individual discrepancies disappear to a large extent; in other words, the errors are compensating, and in the long run the use of volume tables may be expected to yield satisfactory results, provided, of course, that they are suited to the local conditions. The more closely the tables are suited to the local conditions, — the more closely the *conditions of application* and the *conditions of construction* agree, — by just so much may the volume tables be expected to give satisfactory results. If the limits of merchantability are the same; if the log rule used is the same; if the product sawed is of the same average dimensions; if the same standards of soundness have been used in scaling and in measuring the sawed product; then the reliability of suitable tables, carefully constructed, should go unquestioned.

CHAPTER VIII

TIMBER ESTIMATING

39. Definition and General Remarks. — Timber estimating, or timber cruising, as it is often called, is the art of determining the approximate contents of trees, or stands of timber. It may be done entirely by the eye, relying upon past experience to guide the judgment, or instruments may be used to measure the area of the land surface and the dimensions of the trees standing thereon. In either case, it is *always an estimate*, for no one can tell exactly what a stand of timber will yield in the way of merchantable material until the trees have been cut down and the logs sawed into lumber. The practices of half a century ago, when timber and land were both relatively cheap compared with the prevailing values today, were exceedingly rough, and the estimates often fell wide of the mark — usually erring on the safe side. In the present age of rising values and closer utilization, the rough guesses of the early days are no longer acceptable; the estimate must be accurate enough to safeguard the investments made and the expensive equipment now employed by large lumber companies. A difference in the estimate of 10 per cent one way or the other, may be large enough to be the deciding factor in a business venture, and the purchasers of timber now expect a cruiser to submit an estimate which will be within 10 per cent of the actual product. This means that more refined methods of work must be employed. Actual measurement of land surfaces must take the place of the "guess" of the old-time cruiser, or even the maps which were formerly thought to be good enough; * the diameters and heights of trees must be measured with instruments, instead of being judged by the eye; the trees must be counted and tallied instead of merely guessing at the average number per acre; calculations based on sound mathematical principles must take the place of "rules of thumb." In other words, every possible source of error must be eliminated, and the work conducted with all the exactness and precision that time and money will permit. At the best, it will still be an estimate; therefore measurements, where they can be made, should be made accurately, and so far as possible the element of personal choice should be gotten rid of, in order that the results may be perfectly fair and unbiased.

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* Even the maps made by the U. S. Land Office forty or fifty years ago are not above reproach; subsequent investigations have shown that many errors were made, and that little confidence can be placed in maps made so long ago for remote or inaccessible parts of the country.

The improved methods of timber estimating have been devised to meet the more exacting demands of the market due to changes in economic conditions which have followed the development of the country at large. The vast forests of the North and the West, once reckoned as inexhaustible, have been so depleted by wasteful logging and forest fires that the end is in sight; and with the inevitable rise in stumpage prices it has not only been possible, but absolutely necessary, to conduct the work of timber estimating in a more scientific manner. It has thus grown to be an art, and a competent timber estimator no longer relies upon a "sixth sense," but bases his judgment on cold, mathematical calculations. Modern, up-to-date timber estimators employ methods of an entirely different kind than those of the cruisers of fifty years ago.

40. Dependence of Methods on Objects of the Work. — A further cause for greater refinement in the work of timber estimating has been the progress of forestry, especially that branch of forestry known as Forest Management. This term has been defined as "the practice or application of forestry in the conduct of the forest business." * If the forest business is to be conducted successfully it is necessary to know not only the present stock in trade, but how fast that stock is increasing. In other words, while the timber cruisers of years gone by concerned themselves only with the amount of merchantable timber which could then be cut from the stand, present-day practices usually demand not only an inventory of the merchantable stock, but an enumeration of the *immature stock*, with a prediction of *future growth* based on careful studies of the present rate of growth. The business of the forest has assumed *permanency;* the two ideas of *growth* and *future production* have called for data which can be supplied only by a *modern* timber estimate, supplemented by studies of growth and yield which foresters are in a position to conduct. Accordingly, on these grounds, it is possible to recognize two classes of timber estimates, depending on the *objects* for which the work is done:

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* Terminology as adopted by the Society of American Foresters, 1917.

CLASS I. Estimates which are the basis for the purchase or sale of merchantable timber.

CLASS II. Estimates which are the basis for a Forest Working Plan. (A working plan is the plan under which a given forest property is to be continuously managed. See Chapter XII.) On account of their greater detail, these might perhaps be called "Forest Surveys."

Estimates of Class I usually call for the following data:

(*a*) Amounts of merchantable timber (about 12 inches d.b.h., and upward) classified by species and sizes (saw-timber, poles, posts, ties, cordwood, pulp-wood, etc.).

(*b*) Location of the timber with reference to mill sites and markets.

(*c*) Accessibility and estimated logging and milling costs.

(*d*) Market conditions, and estimated stumpage values, by species. No attention is paid to the immature timber, and the whole question of growth is ignored.

Estimates of Class II, or Forest Surveys, are much more elaborate, and should include the following data:

(*a*) Amounts (and often grades) of merchantable timber (12 inches and up) classified by species and sizes (saw-timber, poles, posts, ties, cord-wood, pulpwood, etc.).

(*b*) Amounts of immature timber (less than 12 inches diameter) classified by species and sizes, often going as low as 4 inches, breast-high.

(*c*) Detailed forest description for each type of forest represented in the survey. Types are generally recognized on a physical basis, where possible, and the estimates for each type are kept separate by changing tally-sheets wherever a change in type is encountered. (See Article 48.) The forest description must be accurate, complete, but brief (for outline see Appendix, p. 243).

(*d*) A complete set of the volume tables used, with notes as to local adaptations; or, ample references to standard volume tables.

(*e*) Studies of growth and yield for each commercial species represented. (See Chapters X and XI.) These are usually compiled in tabular form for easy reference.

(*f*) A complete map on a scale large enough to show everything necessary. This will usually include the boundaries of the property, the several forest types, the topography, streams, roads, trails, and cultural features.

(*g*) Location of important stands of timber with reference to mill sites and markets.

(*h*) Accessibility and estimated logging and milling costs.

(*i*) Market conditions and estimated stumpage values, by species.

Detailed instructions for the silvicultural treatment of the several stands of timber and methods of regulating the cut are matters which should be discussed in the Working Plan, and have no place in the timber survey. (See Chapters XII and XIII.) The forest survey should have as its object the compilation of all the facts and figures upon which the working plan is based.

Methods of timber estimating may be classified in another way, *i.e.*, depending on the degree of *accuracy* with which they are conducted. From this point of view, we may recognize three general classes; and the several methods will be discussed in the Articles as indicated:

I. *Ocular methods.* Distances and sizes judged by the eye. Estimates based on the inspection of a very small percentage of the total area — usually not more than 1 per cent or 2 per cent.

See Article 41 for discussion.

II. *Approximate methods.* Distances paced; diameters and heights judged by the eye, but checked by instruments. Estimates based on the inspection of from 1¼ to 25 per cent * of the total area .... Article 42
- (*a*) As applied to surveyed land .... Article 43
  - (*i*) Method of small plots .... Article 44
  - (*ii*) Method of strips .... Article 45
- (*b*) As applied to unsurveyed land .... Article 46

III. *Precise methods.* Distances and areas measured with instruments. Heights measured by hypsometer; diameters measured by caliper or Biltmore stick. Estimates based on 5, 10, or even 20 per cent of the total area.

These methods are further subdivided into
- (*a*) Strip surveys .... Article 47
  - (*i*) Narrow strips .... Article 48
  - (*ii*) Broad strips .... Article 49
- (*b*) Accurately measured plots .... Article 50

41. Ocular Methods. — The methods of Class I (Ocular methods) are often used when a very rapid reconnaissance of an extensive area is wanted with the object, not of using the data gathered for a working plan, nor even of using them as the basis for a specific purchase or sale, but merely to obtain reliable information regarding the location of stands of merchantable timber, their composition, approximate age, condition, accessibility, value, and the desirability of making more accurate surveys later, which surveys would fall under Class II or Class III. They are more in the nature of "exploration cruises," and might be called such. There are relatively few extensive bodies of timber anywhere in this country that have not been cruised, so that the occasions when this method would be appropriate are very rare indeed. For the few occasions that might arise, the very best men obtainable should be employed, for good judgment, based on years of practical experience, is essential to the success of the method.

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* This large percentage of area is inspected only under special conditions, which are described in Article 45.

42. Approximate Methods. — When the work has for its object the accumulation of sufficient data to determine an approximate stumpage value for the several species represented, and such additional information as will enable the investigator to arrive at a definite opinion regarding the value of the timber as a business proposition, then the examination of the timber must be more thorough, and methods of work furnishing these data would be grouped under Class II — approximate methods. There are many methods falling under this head, and in a book of this kind there is not room to describe all of them. In fact the methods are open to so many modifications, invented to suit the tastes and the requirements of the individual estimator, that any attempt at a complete enumeration of the methods would be practically impossible. It will be sufficient, therefore, to describe some of the standardized methods, which are typical. Practically all of the methods aim to secure a reliable estimate of the timber by species, sizes, classes of material, etc., and a map which will be sufficiently accurate and detailed to plan the logging operations. Descriptions of the stands, estimates of the cost of logging, and other points of interest, are generally included so that stumpage prices can be fixed; but no studies of growth and yield are made. The percentage of the area actually covered may range from 1 or 2 to 5 per cent, and since a knowledge of *area* is so essential to the success of any of these methods, the logical way to classify them is according to whether or not the land has been surveyed and the boundary lines permanently marked. (Interior lines as well as exterior lines.)

43. Approximate Methods as Applied to Surveyed Land. — By surveyed land, in this connection, is meant land that has been divided, by survey, into units six miles square (called townships), and each township then subdivided into 36 square miles (called sections),* all numbered and referred to certain established base-lines and meridians, according to methods prescribed by the U. S. Public Land Office.* The establishment of permanent corners on the ground, the blazing of trees along the lines, and the sets of descriptive notes accompanying the sketch-maps, — all done according to a uniform system provided for by the government, — did much to make the work of orientation and area determination easy; and where the marks of the original surveys have not been obliterated orientation is still a comparatively simple matter. Contrasted with these rectangular surveys are the ordinary surveys by metes and bounds, and these are not nearly so readily handled by the timber estimator. Unless the parcels of land are relatively small (*i.e.*, 160 acres or less), and unless the survey lines are plainly marked, both on the ground and on the map, it is usually necessary to run some preliminary lines before the work of timber estimating can begin. Moreover, the lines of metes and bounds surveys are apt to be so irregular, and the work of such questionable accuracy, that it is frequently necessary not only to run a straight line as a base-line, but to retrace the exterior lines, for the purpose of securing the necessary control. All this work is superfluous in country that has been subdivided into rectangles; the straight lines running due north and south, or due east and west, furnish admirable base-lines from which to start the cruising lines, and also make it easy to keep a constant check on the work. Areas are calculated with a minimum of trouble. Orientation is always simple. The work can be planned and executed with comparative ease. In order to explain the methods applicable to surveyed country, the following diagram of a township, with its sections and subdivisions, is shown.

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* The townships of Maine and the Adirondacks, surveyed before Congress had adopted the standard form of survey employed in the western states, have no definite number of sections; and the system of numbering them differs from the system used in the U. S. Land Office.

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* For a complete treatise on the method of making these surveys, see "Manual of Instructions for the Survey of the Public Lands of the U. S.," Washington, D. C. A synopsis of the chief points which concern the woodsman will be found in Part I, Section VIII, of Austin Cary's "A Manual for Northern Woodsmen," Cambridge, Harvard University Press, 1918. Unfortunately, the field-work was not always done with the required precision, and the descriptive notes are not always as complete as they should have been.

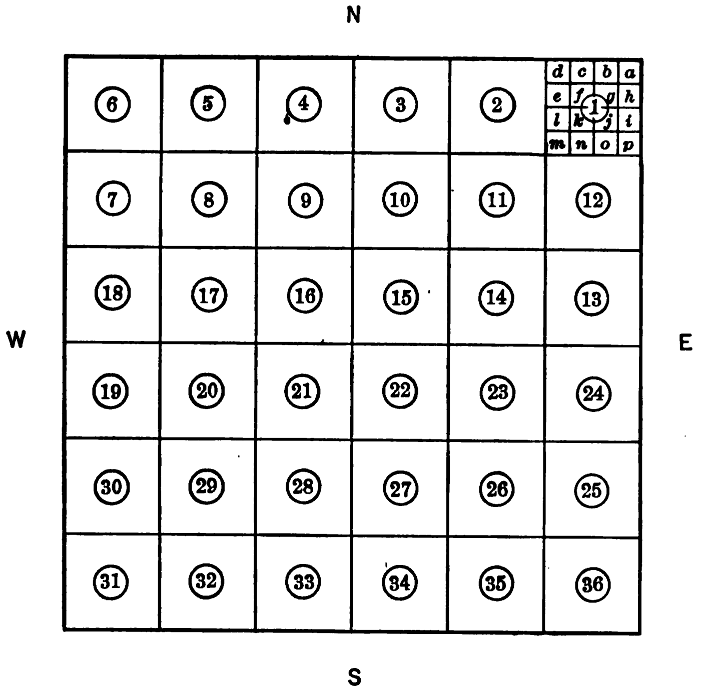

FIG. 11. Diagram of a Township.

1 township = 36 square miles = 23,040 acres.
1 section = 1 square mile = 640 acres.
1 "forty" = $\frac{1}{16}$ square mile = 40 acres.

(The small squares in Section 1, lettered alphabetically *a* to *p*, are each $\frac{1}{4}$ mile square and are called "forties.")

44. The Method of Small Plots. — The first thing to do is to decide what proportion of the total area shall be inspected and measured. This will depend on the character of the country, the density of the timber, and the regularity of the stands. If the topography is not too uneven, if the stands are open enough to allow the estimator to see a distance of approximately 40 rods ($\frac{1}{8}$ mile) on either side of his line of travel, and if the stands are quite regular, then it may be safe to base an estimate of this character on the detailed examination of $1\frac{1}{4}$ per cent of the total area. Such a percentage would be obtained by taking two plots of $\frac{1}{4}$ acre each, or one plot of $\frac{1}{2}$ acre, in each forty-acre subdivision. A more irregular stand, or one situated in rough country, would make it necessary to increase the percentage of area examined to 2½ per cent, or a total of 1 acre in each forty. Four ¼-acre plots so spaced that the estimator's lines of travel would not make it necessary for him to see more than 330 feet ($\frac{1}{16}$ mile) on either side of his compass line, would then be preferable. The plots mentioned may be measured with the least delay and effort if they are circular in outline; this form of plot can be measured easily by one man working unassisted, and it is to be recommended as better for this kind of an estimate than a rectangular plot.

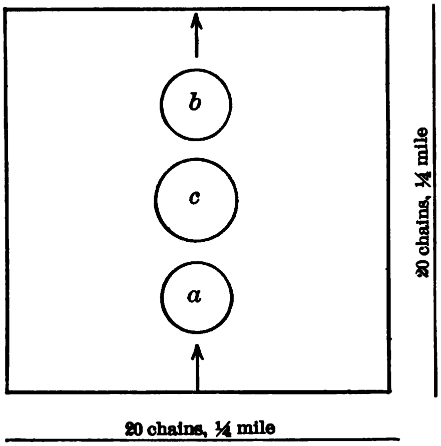

FIG. 12. Method of Small Plots 1¼ Per Cent Estimate.

If it has been determined that a 1¼ per cent estimate will be sufficient the estimator will plan to travel once across the center of each forty, as shown in Fig. 12. Two plots, *a* and *b*, each ¼ acre in area, and spaced ⅛ mile apart, or one plot ½ acre in area *c*, located in the center of the forty, may then be estimated.

If a 2½ per cent estimate has been determined upon, then the plots should preferably be ¼ acre in size, and four of them distributed, equidistantly, as shown in Fig. 13.

In this case the forty is traversed twice, plots "*a*" and "*b*" being established one-eighth mile apart on the first line run through the forty, and plots *c* and *d* established on the return line, which is ⅛ mile distant from the first line, and parallel to it.

The work of estimating the timber on these circular plots consists in tallying the trees by species and diameter-classes (d.b.h.) on a form of tally-sheet prepared in advance.* The form of tally-sheet employed depends on the method of work being followed, and may be similar to the form shown in Fig. 14, which is sufficient when reliable volume-tables are available; or the tally-sheet may take the form shown in Fig. 15, which is especially desirable when no reliable volume-tables exist.

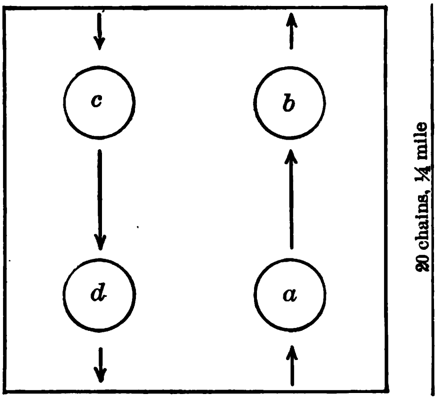

FIG. 13. Methods of Small Plots 2½ Per Cent Estimate.

Location.................... *Plot No*......................
Date...................... *Type*..........................
Area of Plot............... *Name of Cruiser*...............

Diam.	Species.	Species.	Etc.	Etc.	Etc.	Etc.	Etc.
6							
7							
8							
Etc.							

FIG. 14. Form of Tally-sheet to be used when Volume Tables are Available.

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* This is to save time in the field. Note-books can be prepared each night for the work of the following day, thus avoiding delay.

Location............ *Plot No*..............
Date................ *Type*.................
Area of Plot......... *Name of Cruiser*............

Diameters.	Species.			Species.			Species.			Species.			Etc.
	Trees	Logs	½ logs	Trees	Logs	½ logs	Trees	Logs	½ logs	Trees	Logs	½ logs	
5	Trees tallied by diameter breast-high.	Logs tallied by top diameter, outside bark.	½-logs, tallied by top diameter, outside bark.										
6													
7													
8													
9													
Etc.													

FIG. 15. Form of Tally-sheet to be used when Volume Tables are not Available.

The measurement of diameters at breast-height is usually done by eye, checked frequently by calipers or Biltmore stick. The measurement of height is also by eye, but checked by hypsometer occasionally. In the case of inexperienced men, however, the use of instruments should be required until a considerable degree of proficiency in ocular judgment of sizes has been acquired. While the diameter at breast-height, and the total height, or height at the top of each merchantable log can be measured with the aid of instruments, the estimation of the top-diameters of the several logs is purely a matter of comparison and judgment.* It is in this work that the skill and experience of the estimator play such an important part. A careful study of the taper of stems of fallen trees will aid materially in this work of judging taper on standing trees, and such studies on wind-thrown or felled trees are strongly recommended.

The absence of reliable volume tables makes it very desirable to estimate in terms of logs of standard size, and for this work, the tally-sheet shown in Fig. 15 should be used, and the trees estimated in terms of the standard 16-foot log.

The advantages in using 16-foot logs are: (1) they are perhaps the commonest of the standard length logs, and (2) the corresponding half-log (8 feet) is the smallest practicable unit for estimating, and usually the smallest merchantable unit.

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* Unless a dendrometer be used. See article 19.

While it may seem that the estimating of log-lengths and top-diameters in standing trees is a matter of so much guesswork that the resulting figures will be inaccurate and of little value, it should be pointed out that the method has the advantage of allowing the exercise of considerable judgment as to the division of the stem into merchantable logs (eliminating bad crooks and defects, and providing for such occasional forms as forked trees) and that unless the estimator's eye is grossly inaccurate, the results obtained will, in all probability, be better than figures gotten by applying volume tables of questionable accuracy. As in all timber-estimating, practice is very necessary to insure accuracy and reliable results, and no opportunities should be lost to check up one's judgment of taper, sizes, diameters, etc.; for only by so doing can one expect to attain a creditable degree of skill.

It will be noticed that the tally-sheet (Fig. 15) provides for the entering of top-diameters *outside bark*. This means that a deduction for bark must be made before scaling the logs to determine their contents. For any particular region, it is generally advisable to make up a table showing the average thickness of bark, according to species and diameter of log; then by taking *twice* the average thickness of bark* a table can be constructed to show the average number of inches to be deducted from a log-diameter, so as to give its proper scaling diameter. Such a table might well take the form shown in Fig. 16, and

Species.	Deduct 1 inch.	Deduct 2 inches.	Deduct 3 inches.
Douglas fir	on logs from 6" to 12" d.o.b.	on logs from 13" to 20" d.o.b.	on logs above 21" d.o.b.
Western yellow pine	on logs from 6" to 10" d.o.b.	on logs from 11" to 15" d.o.b.	on logs above 16" d.o.b.
Etc.	Etc.	Etc.	Etc.

FIG. 16. Bark Deductions for Standard Logs.

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* Twice the thickness of bark is taken because in measuring the diameter of a log with the bark on, the bark is included at both ends of the diameter.

should in all cases be made up from measurements taken on logs cut in the immediate locality.

This method of estimating the size of logs in the tree, then making the appropriate bark allowances, in order to apply a log rule, might be spoken of as "scaling on paper," and it yields figures which may then be totaled to show the contents of the entire plot, by species.

The advantages of the small circular plot method of estimating timber may be stated as follows:

(1) One man can do the work unassisted, since there is no need to establish corners, or run the boundary-lines of the plots.

(2) The trees can be counted and estimated, in many cases, without moving from the center of the plot. It is therefore rapid.

Care should be exercised to avoid the following sources of error:

(1) Misjudgment of the radius of the plot, with a consequent overestimate or underestimate of the required area.

(2) Misjudgment of diameters and sizes. Frequent checking with the calipers and hypsometer will help to reduce errors of this kind.

The size of the circular plots should in all cases be chosen to suit the character of the stand. In dense stands of great regularity, the plots need not be larger than ¼ acre (radius = 59 feet). In very open, irregular stands (western yellow pine in the Southwest, for example) it would be safer to take plots of 1 acre (radius = 118 feet). For stands of intermediate character, an area of ½ acre might be chosen (radius = 83⅓ feet). The frequency with which plots should be established along a compass-line depends on the objects of the work and the degree of accuracy required. Only in rare cases would more than 5 per cent of the total area be covered by the method; for if a greater proportion of the area is to be covered, one of the strip methods (see Article 47) would accomplish the work to better advantage.

The addition of a few brief notes regarding the condition of the timber on each plot is to be recommended, but the description should not be so detailed as outlined in Appendix (page 243).

The method of small plots provides a simple means of getting an estimate of the standing timber on small areas at intervals along a compass line. It is necessary, however, to know the character and distribution of the timber on the remainder of the area, in order to be sure of securing a reliable estimate. This is accomplished by mapping the stands of timber along the compass-line according to type, each type being represented by an appropriate color, cross-shading, or symbol. In this way, all barrens, burns, parks, or other non-timbered areas are noted, and if the estimator uses care and discrimination in the recognition and in the designation of types (not only on the plots but also in the stands of timber he passes through, or observes adjacent to his line), he may feel some degree of confidence that the *plots* are fair samples of the *stands*. On the map, as drawn later, the area of the several types can be determined accurately with a planimeter and the total estimate figured as described in Article 55.

45. Method of Strips. — Under certain conditions it may be easier, quicker, and fully as accurate to count trees on strips, instead of on circular plots, and then by the application of volume tables, or the method of ocular division into logs just described, make an estimate of the approximate contents of an entire stand. The conditions under which this method is to be recommended are as follows: (1) The stand of timber is irregular, with open spaces too numerous to be mapped accurately by the method of small plots, just described. (2) The stand of timber is very open, with but few merchantable trees per acre. (3) The estimate calls for data on one or more selected species, which occur scattered through the stand irregularly.

It is obvious that the use of plots in these circumstances would be unreliable, and therefore continuous strips, of a width to suit the peculiarities of the case, are employed. These, by reason of their continuity, will yield results much more likely to be representative of the entire area.

The work can be done to good advantage by three men, one of whom runs the line through the country by means of a compass, and keeps track of the distance by pacing, while the other two count and tally trees for a stated distance on either side of the line. Each estimator should carry a caliper or Biltmore stick to check the ocular judgment of diameters, and he should use a tally-sheet of the form shown in Figs. 14 or 15, according to requirements, tallying the trees on his side of the line as he progresses through the stand. The compass man usually carries a barometer and makes a topographic and type map as he goes along. The strips may be one chain wide, or two chains wide, or even as much as 5 chains wide. In open yellow pine stands, strips as wide as 5 chains have been found feasible, and the great gain in area covered has more than offset any slight loss in accuracy due to the somewhat difficult task of gauging the width of the strip. Since each forty-acre subdivision is traversed at least once, these strips will cover, according to their widths, a percentage of the entire area as follows:

	1 chain wide.	2 chains wide.	5 chains wide.
Strips run ¼ mile apart (= once through each "forty")	5%	10%	25%

Variations of the strip method, as thus described, are numerous, and may be devised to suit the needs of the particular type of country and timber that is being traversed; or the methods may be modified to meet the requirements imposed by the *object* of the cruise. For some such variations the reader is referred to "The Woodsman's Handbook," * pages 68 to 71 and "Forest Mensuration," † pages 191–201.

46. Approximate Methods as Applied to Unsurveyed Land. — The problem presented here is first to find the area of the tract of land to be estimated. Many old metes-and-bounds surveys are decidely inaccurate; and in all cases where doubt exists as to the reliability of the maps, or where the area is an unknown quantity, a traverse must be run, as described in Article 3 and the area computed or determined by planimeter. Once this is done, a system of parallel traverse-lines can be laid out so as to cross the tract at right angles to the ridges and streams, and the method of small plots, or strips, can be applied as just described (Articles 44 and 45). The parallel strips afford an opportunity to map the topography and forest types, and the boundary-survey will be a valuable control for both.

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* Bulletin 36, U. S. Forest Service, by Graves and Ziegler, 1910.

† "Forest Mensuration," by H. S. Graves, N. Y., John Wiley and Sons, Inc., 1906.

47. Strip Surveys. — Strip surveys constitute the first of the two classes of precise methods of timber estimating mentioned in Article 40. The distinguishing feature of these surveys is the use of instruments for measuring distances, areas, and dimensions of the trees. Nothing is left to estimation or judgment except the *width* of the strip, and this should be checked frequently by pacing. In cases involving the inclusion or exclusion of a large tree, situated so close to the edge of the strip as to make it impossible to tell without measuring, whether it belongs in or out of the estimate, the distance from the center of the strip to the edge of it should be measured with the chain (or tape), so as to remove all doubt. If the tree in question is not within the strip by half or more of its diameter, it should be excluded. Besides using instruments to insure accuracy in measurements, strip surveys generally cover a larger percentage of the total area than do the plots of the approximate methods. Depending on the density and regularity of the stands, 5 per cent, 10 per cent, or even 20 per cent of the total area may be covered by the strips. The commonest practice is to run parallel strips 10 chains ($\frac{1}{8}$ mile) apart, which will usually give the required degree of control for topographic and type mapping. If the strips themselves are 1 chain wide this means that a 10 per cent estimate is secured.

Other modifications are:

(1) 1-chain-wide strips (narrow strips), 20 chains apart; 5 per cent estimate.

(2) 2-chains-wide strips (broad strips), 20 chains apart; 10 per cent estimate.

(3) 2-chains-wide strips (broad strips), 10 chains apart; 20 per cent estimate.

The conditions under which these different methods are used will be described in the following article. The organization of the crew and the duties of each man in it will also be described fully in their appropriate places.

48. Narrow Strips. — When the stands of timber to be estimated lack the regularity of even-aged, or pure stands; when they present many or frequent changes in forest type; or when they are so dense as to make the judgment of a wide strip difficult, and the visibility of the timber between strips impossible; then the narrow strips (66 feet, or 1 chain) are to be recommended. The mixed hardwood and coniferous forests of the Northeast, or the irregular forests of the Appalachian Mountains are good examples of the kinds of stands to which the narrow strips apply. If the topography is so broken and irregular as to make it impossible to see the country adjacent to the strips for as much as 330 feet, then it may even be necessary for one or more members of the crew to make occasional excursions to the side, in order to be sure that no important changes in type are being overlooked. But generally speaking, a 10 per cent estimate conducted in this manner will yield satisfactory results provided proper care is exercised to avoid inaccuracies. The work is conducted as follows:

Parties of three, four, or five men can do the work; where five men can be used, the highest degree of efficiency will be secured, and the duties may be distributed in the following manner: one man, usually designated as the compass-man, handles the compass and acts as head chainman. He also carries a note-book in which the topography is sketched as he proceeds along the line of travel. He keeps a tally of the distance run, and indicates on the map not only the topography, but the boundaries of forest types, streams, roads, fences, cabins, and other features the location of which would be of value in a forest map. A second man, who is generally designated as the tally-man, carries the note-book in which the trees on the strip are recorded, by species and diameter-classes, and in which the forest descriptions are written (see Article 40). He also acts as rear chain-man, and should keep a tally of the distance traveled as a check on the compass-man. The frequency with which mistakes occur through omitting to tally the distance, especially in inexperienced crews, makes this check almost indispensable. Two other men, called caliper-men, work on either side of the chain (or tape) and measure the diameter of all trees (within specified diameter limits) that stand within 33 feet ($\frac{1}{2}$ chain) of the center line of the strip, which can always be identified by the position of the chain on the ground. The accuracy of the estimate depends largely on the care with which the caliper-men perform their tasks; if they are careless in measuring the diameters of the trees, or if they misjudge the limits of the strip, or call in trees by the wrong name, large errors may result. Therefore, while this part of the work is admittedly the most mechanical and monotonous, it is extremely important that errors here shall be guarded against, and for this reason the work of the caliper-men should be constantly supervised by the man in charge of the party, — the captain, — who is the fifth man in the crew. He should assume the responsibility of the work of the entire party, and besides this supervisory work, he should make observations on the silvicultural condition of the stands, the physical conditions of the site, and should be ready to dictate to the tally-man the data which constitute the forest description. (See Appendix, page 243.) The forest description should be written for each type passed through, or, if conditions warrant it, even for each acre tallied. This task, although likely to become somewhat monotonous, should never be done in a perfunctory manner, for it is of great importance.

Where five men are not available, it is possible to conduct the work fairly well with a crew of four. In this case, the duties of captain devolve upon the tally-man, who must then take time to supervise the work of the caliper-men. The caliper-men, if they have had sufficient training and experience to qualify them for the work of forest description, can render valuable assistance by reporting to the tally-man the silvicultural descriptions. The thoroughness with which the caliper-men cover the ground should enable them to perform this task very satisfactorily, but it sometimes happens that they have not had the requisite training for this kind of work. With four men the strip-running progresses not quite so rapidly as with five, but it may safely be done by this number of *experienced* men. Reducing the number to three, by which the compass-man is overloaded, since he must generally assume the work of tallying the trees, seriously impairs the efficiency of the crew. It means that the caliper-men are idle while the compass-tally-man is getting his line of sight with the compass, and that this one man has far more than his share of work to do. Under some circumstances (*i.e.*, where the trees are so scattered that the caliper-men tally their own trees, or where no map is necessary) it may be possible to get along with three men, in which case one of the caliper-men should act as rear chain-man; but it should be employed only as a last resort.

The work of chaining the distance in these strips should always be done carefully, and surface measurement of sloping ground is to be strictly avoided.* This means that in hilly country a plumb-bob is a necessary appurtenance, to be used by the rear chain-man in going up hill, and by the head chain-man in going down hill.

49. Broad Strips. — Where the stands of timber are sufficiently open to warrant it, and especially when experienced caliper-men are employed, who can judge with precision the width of strips up to 2, 4, or 5 chains, broad strips may sometimes be used to advantage. As pointed out in Article 45, the gain in area covered will frequently more than offset the slight errors due to misjudging the correct width of the strip. The method here described differs from that in Article 45 in that the length of the strip is measured with chain, or tape, and the crew is composed of four or five men; the trees are calipered, and practically all the work is done with a greater degree of refinement. The method is employed in open country or scattered timber where the necessity for an accurate map is of prime importance. The details of the method are similar in all respects to those already described for narrow strips.

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* If desired, distances can be measured along the surface of the ground, and automatically corrected for slope, by means of a "slope tape," so graduated that the necessary corrections can be applied when the per cent of grade is known.

50. Accurately Measured Plots. — If the several stands in the timber to be estimated are very uniform and regular in character, and present no special difficulty to the problem of selecting a few sample acres that shall be in all respects *representative* and *average*, then the method of accurately measured plots may be used. As the name implies the plots are measured carefully; and the calculation of the volume of timber on the plots is done with as much care as the measurement of the area of the plot. In addition to being used in even-aged stands of great regularity, this method may be employed as a check on the estimates made by the strip method, in which case a few sample plots are established in each forest type. The ablest man in the party should make the selection of the plots, for it requires a nicety of judgment and a skilful eye to select a plot which will be a fair average of conditions over an extensive area.

The size of the plots should correspond to the density of the stand; in lodgepole pine, or eastern spruce, an area of one acre will suffice, but in more open stands, like southern yellow pine, or western yellow pine, a plot should be large enough to insure average conditions, and plots as large as 2, 5, or even 10 acres may be necessary. It should be said by way of warning, however, that if the stands are so open and scattered as to require a very large plot, the usefulness of the method becomes open to question. Plots of one acre are standard, and the shape of the plot may be square or rectangular, to suit the needs of individual cases. If laid out with a tape graduated in feet and tenths, a square plot (208.7 feet on a side) is very satisfactory; if a chain be used, then a rectangular plot 4.0 x 2.5 chains is acceptable. Great care should be used to have the area exact; the lines should intersect at the corners exactly at right angles and a compass or a staff-head will be found indispensable to this work. Corner stakes are usually set, sometimes temporarily, sometimes permanently, if for any reason it may be necessary to return to the plot again for future measurements. To prevent tallying trees outside the boundaries of the plot, a string or cord may be stretched from one corner-stake to the next, or the outside tree may be blazed or otherwise marked in a distinctive way.

The trees are measured carefully at breast-height, and recorded according to species, diameter, and sometimes according to height-classes. Instead of tallying only the merchantable trees, it is customary to record all trees that will fall in the 4-inch class, and upward; or, if deemed necessary, the record may include trees of 2 inches in diameter and upward. The saplings and seedlings are counted on one or more smaller plots, which may be one square rod in area, and established within the large one. A very careful forest description * is then written, as a guide in determining the details of silvicultural treatment of the stands.

If the carefully measured plots are established for the sole purpose of checking the strips, then the average stand per acre as determined for a given type by the strip method is compared with the average stand per acre as obtained on the plots, and any marked differences noted. If such differences indicate inconsistencies and disparities which affect the total number of trees per acre or the distribution of the diameter-classes, it may be sufficient cause to question the accuracy of the work done on the strips. It will then be advisable to re-run one or more strips, as a check on the work, taking more than usual precautions to secure accuracy. Or it may be desirable to select other plots, with a view to detecting just where the inconsistencies lie, and to what factors they are due. In either case, the work should be investigated until a satisfactory conclusion is reached by the man in charge of the work, and the estimates should be adjusted accordingly.

If the plots are established for the additional purpose of volume determination and growth studies, then one of the several methods of volume calculation, described in standard texts on Forest Mensuration,† may be applied. There are several of these methods, but since most of them are of purely academic interest to the American forester, only two of them will be described here. The first one, called the Mean Sample Tree method, is applicable to stands of even-age and great regularity;

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* See Appendix, page 243, for the points to be covered in this description.

† See H. S. Graves, "Forest Mensuration," Chapter 14, N. Y., John Wiley and Sons, Inc., 1906.

the second one, called the Volume Curve Method, can be used to good advantage where the conditions are not so uniform.

51. The Method of the Mean Sample Tree. — The trees on the plot are measured and tallied by species and diameter-classes of even inches. Then, since the volumes of trees of approximately the same age and height (conditions under which this method is reliable) vary very nearly as their basal area, the basal area for each diameter-class is computed, and the total basal area for the entire plot is determined. (See example in Fig. 17.) If more than one species is being studied, then the mean sample tree for each species must be determined separately. The total basal area, divided by the number of trees of that species on the plot gives the average basal area, from which the corresponding diameter can then be determined. Three or more trees of this diameter are then selected, care being taken to choose trees which represent average development as to stem, crown, and general condition; these trees are felled, and divided up into sections; the volumes are computed by applying the appropriate formulæ (see Article 25), and averaged together to obtain the volume of the average, or mean, tree. This figure, multiplied by the number of trees on the plot (of that species), will give the total volume of all such trees on the plot.

Locality.............. *Type*..............................
Date................. *No. of Plot*.......... *Area*........

D.b.h.	No. of trees, by species.			Sample trees.	
	Spruce.	Basal area.	(Other species).	D.b.h.	Vol.
8	15		Etc.		
9	21		Etc.		
10	32				
11	24				
12	7				
13	2				
Total......	101				
Mean......	....				

Total vol. (by species) on plot ....

FIG. 17. Volume Determination by the Mean Sample Tree Method.

The presence of more than one species complicates the work, since the volume has to be worked out separately for each species, and the method is, therefore, not recommended where several species are represented.

It is not always practicable to find sample trees of exactly the required diameter. The average diameter will usually work out to be a number with a fractional part of an inch, and it is necessary, in selecting the sample trees, to get diameters of exactly this size, if possible; but if impossible, trees should be selected that fulfil the requirements as nearly as may be, and then the calculations adjusted in the following manner:

Let B = the basal area of entire plot.
" b = the basal area of the sample trees.
" V = the volume of the trees on the entire plot.
" v = the volume of the sample trees.

Then $v : V = b : B$

and $V = \frac{vB}{b}$.

For a full discussion of this method, and the conditions under which it may be applied see Graves, loc. cit.

52. The Volume Curve Method. — Where the range of diameters on the sample plot is large (more than six or eight inch-classes) as would be the case in a stand which is uneven-aged, the following method devised by H. S. Graves, and described in his text-book already referred to, will be found useful.

Tally the trees by species and diameter-classes. Then, according to the number of the trees and their range in sizes, select arbitrarily from 5 to 7 sample trees, and distribute them so as to represent some of the small diameter-classes, some of the large diameter-classes, and some of the intermediate diameter-classes. (See example worked out in Fig. 18.) Fell these trees which, of course, should each be representative and normal, so far as can be judged, and compute their volumes by the application of the appropriate formulæ. Then, on coördinate paper, plot the volumes of these trees, using the diameter-classes as the abscissæ

Locality............ *Type* ....
Date............... *No. of Plot*........... *Area*.......

D.b.h.	No. of trees by species.			Sample trees.	
	Pine.	Basal area.	Other species.	D.b.h.	Vol.
6	4		etc.	7.2	
7	2		etc.	10.9	
8	8		etc.	14.2	
9	6			17.8	
10	12			20:1	
...	...				
...	...				
...	...				
...	...				
...	...				
20	2				
21	1				
etc.					
Total....	35				

FIG. 18. Volume Determination by the Volume Curve Method.

(horizontal scale) and the volume as the ordinates (vertical scale). Draw a smooth curve through the points thus obtained, and from it may be read the volume-values for trees of all diameter-classes. The number of trees of each diameter-class multiplied by its appropriate volume-value gives the volume of each diameter-class; these, in turn, added together, will give the total volume of all trees of that particular species on the plot.

This method has the following features to recommend it: (1) It involves no laborious calculation of mean sample trees, but enables the direct and immediate choice of such trees. (2) Any errors in judgment and selection of sample trees can be detected automatically when the volumes are plotted on coördinate paper.

The sample trees felled on plots thus measured afford an excellent opportunity to study growth; in fact it would scarcely be worth while to employ the method of sample trees for the sole purpose of volume determination. In most cases where an estimate is being made as the basis of a working-plan, however, a knowledge of growth is fully as important as a determination of the volume, and the usefulness of these methods will appear more clearly when the subject of growth is treated. (Chapter X.) To lay out plots, fell the sample trees, and compute the volumes, is costly and time-consuming work; and the need for it should be urgent and well-considered before undertaking it.

53. Factors Affecting the Accuracy of Timber Estimates. — The chief factors affecting the accuracy of timber estimates made by any of the methods described, are herewith enumerated in order that the man in charge of such work may know what to guard against.

(1) The percentage of the area covered by strips, or plots.
(2) The accuracy in chaining distance, and in estimating the width of the strip.
(3) The accuracy in measuring the trees.
(4) The elimination of dead and worthless trees (visible defect).
(5) Allowance for unsound trees (hidden defect).
(6) Applicability and accuracy of the volume tables used in computing the contents of the trees tallied.
(7) Care in distinction of types.
(8) The accuracy of the map on which types are plotted and from which areas are calculated.
(9) Misnaming species of trees.

The means to be used in guarding against errors will readily suggest themselves, and it is the duty of the captain of the crew to keep a watchful eye on all the operations of the men in his charge.

54. The Cost of Timber Estimating. — Any work which is susceptible of so many variations, as just explained in the preceding paragraphs, will naturally exhibit a wide range in costs. In fact, timber estimating can be made to cost almost any figure, above the irreducible minimum of a hasty ocular estimate, and as a matter of fact the method of timber estimating employed will be determined, at least in commercial work, by the amount of money which can be expended upon it. In these days of rising costs of labor, food and supplies, it is almost impossible to give any definite figures; but the following table, based on subsistence at $1.00 per day, unprofessional or ordinary labor at $2.50 per day, professional service $5.00 per day, with additional cost of camp maintenance and moving camp, may be accepted as approximately correct for prevailing conditions.

COST OF TIMBER ESTIMATING

(Exclusive of the Computations and Maps)

Class of estimate.	Approx. cost per acre.
1. Ocular estimates	Variable; from $0.001 to $0.01
2. Small plots 1¼ per cent of area	from $0.01 to $0.015
3. Small plots, 2½ per cent of area	" $0.015 to $0.02
4. Strips (approximate method)	" $0.05 to $0.07
5. Strips (precise; 10 per cent of area)	" $0.12 to $0.15
6. Accurate plots	Cost per plot from $5.00 to $10.00 depending on size of plot, density of stand, and number of sample trees cut.

55. Computing the Volume of Stands from the Tally-sheets. — There are two methods of doing this work, both of which call for suitable volume tables: (1) The volume tables may be applied directly, and the contents in board feet, cubic feet, or other unit obtained for each tally-sheet (acre or fractional part) by species and diameter-classes. This involves a large number of computations and unless there is some special reason why each individual acre should be so worked out, the second method is easier and quicker. (2) All the acres tallied are classified according to the forest types recognized; then all trees of the same species and the same diameter-class are added together, and divided by the total number of acres of that particular type, with the result that a table can be constructed showing the *average number of trees per acre*, by species and diameter-classes. Such a table is called a *stand table*. The next step is to multiply the stand-table values by the appropriate volume-table values, with the result that a *stock table*, so-called, is obtained. Stand tables and stock tables, being in terms of a *unit of area* (usually the acre in this country), are of special value when it is desired to make comparisons of one type with another, or to study the relative distribution of the size-classes; and they are, therefore, to be recommended. From stock tables, the merchantable stand for the entire type can readily be computed, and by adding together the totals for the types the grand total for the entire tract is obtainable.

The methods employed in working up the tally-sheets should always be chosen so as to fulfil to the best advantage the purposes for which the survey was conducted. If the working plan calls for any unusual classifications of merchantable material, due regard to these requirements must be had at the time of making the computations. This kind of work is best done by a corps of expert mathematicians, who have the necessary adding machines, slide rules, and comptometers to perform the task quickly and accurately. The need for accurate, complete, lucid field-notes and descriptions must now be apparent, for the men who do the computing cannot be expected to interpret ambiguous notes satisfactorily.

CHAPTER IX

THE AGE OF TREES AND STANDS

56. Practical Value of a Knowledge of Age. — The element of time has an extremely important bearing on many of the problems of forest management. It is very necessary to know at what age certain species of trees mature and it is also very desirable to know at what age the products of intermediate cuttings (thinnings) may be expected to yield some financial returns. The time element is of special importance to the forest owner because it takes a long period of years (30 to 80 years or more) for the timber crop to mature. The farmer sows in the spring and reaps a harvest in the fall, and turns over his money once a year; the merchant and manufacturer buy and sell constantly, turning over their money at least once a year, and sometimes much more frequently. But the timber owner, whether he owns a large tract or a small tract of timber, must reckon in terms of decades; and in a growing number of instances the investments of the present are being made for long terms. As the supply of standing timber in the country diminishes, an increasing number of lumber companies are retaining possession of their lands, and they are figuring on a second cut within 10 or 20 years and repeated cuts thereafter. This is particularly true of pulp-wood owners in the North, and owners of yellow pine lands in the South. The length of time during which money must be invested in standing timber, until it becomes of merchantable size, is, therefore, one of great importance; and it is closely related to the whole subject of the age of trees and stands.

57. Age of Seedlings. — Seedlings, because of their small size and the ease with which their ages may be determined, will be discussed first. They also have an important relation to other age-problems (see Article 59), making it necessary to begin with them.

In the case of seedlings of coniferous trees (pines, firs, spruces, etc.), the age may be determined quite accurately by counting the whorls of branches, since under normal conditions each whorl represents one year's growth. Even when the branches are not present, there are frequently marks or scars to indicate where they once grew, so that the age of trees of considerable size may be ascertained approximately by this method. Seedlings of the broadleaf trees (oaks, maples, birches, etc.), do not display the same regularity in their branching habits, and after the third or fourth year it may indeed be almost impossible to tell the age of such seedlings without resorting to other methods, soon to be described. If age *only* is wanted, it will suffice to uproot the seedling and make a clean cut with a sharp knife at the root-collar; the number of annual rings of growth can then be counted, beginning at the pith and counting outward on a radius, to the bark. If further information be needed, such as rate of height-growth, additional cross-cuts and measurements will be necessary (see Article 58).

58. Age of Felled Trees. — It is a comparatively simple matter to determine the age of a felled tree, provided the stump is sound and it shows the annual rings of growth distinctly. The counting of the annual rings is not always easy, especially if the growth be extremely slow, or if the species be one in which the differentiation between spring wood and summer wood is not clear.* A sharp knife that will make a clean cut is absolutely essential, and a magnifying glass is often a great help, especially in counting the rings of spruce, hemlock, maple, and other species of slow growth. To determine the age of a felled tree it is necessary to know not only the number of annual rings represented on the surface of the stump, but also the number of years required to reach the height of the stump. This will vary not only with the species, but even with the individual tree; fortunately, in most studies of age, an approximation will be sufficient;

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* Annual growth rings show up clearly in most conifers because of the larger amount of resin present in the summer wood, as contrasted with the spring wood. The rings of the so-called "ring-porous" woods among the broadleafed species (oaks, hickories, ashes, etc.) also show up clearly. The rings of the so-called "diffuse-porous" woods (maples, gums, etc.) are frequently very difficult to count.

mon merchantable size. When the field measurements are completed, all trees of the same breast-height diameter-class * are thrown together; the diameter values for the level of 1 foot are then averaged together, those for the level of 2 feet are averaged together, and so on, for the 3-foot level, the 4-foot level, the 4.5-foot level (d.b.h.) and the 5-foot level. As a result, there are obtained the *average diameters* of trees of a specified d.b.h. class at heights above the ground of 1 foot, 2 feet, 3 feet, 4 feet, 4½ feet, and 5 feet. From these figures, computed similarly for all the different diameter-classes, a set of harmonized curves is drawn on coördinate-paper, observing the rule that although the *average* of the d.b.h. measurements for any particular class might not have come out in terms of an even inch (*i.e.*, with no decimals) the final, harmonized curves must be drawn so that they intersect the 4½-foot ordinate at even inch-classes. (See Fig. 20, in which

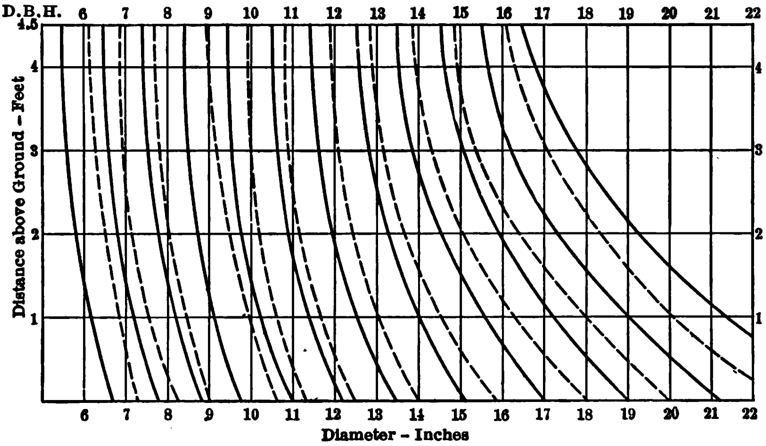

FIG. 20. Showing Stump-taper Curves Harmonized.

Note: Dotted lines show actual averages, as determined from a large number of field measurements. Solid lines show harmonized curves, dividing the cross-section paper into diameter classes.

* When measuring to tenths of inches, all those values having a decimal of *more than* 0.5 are thrown into the class above; those with 0.5 *or less* are thrown into the class below; *i.e.*, 8.6 inches is considered as belonging to the 9 inch-class; and 8.5 inches to the 8-inch class, etc.

the dotted lines are the original curves, the solid lines are the final, harmonized curves, forming inch-classes at breast-height.)

From these curves, a set of which is prepared for each species studied, it is possible to assign any stump to its appropriate d.b.h. class. For example, it is desired to throw a stump of spruce, measuring 18.2 inches outside bark, into its proper d.b.h. class. The average height of the stump is 1.2 feet, at which point its average diameter is 18.2 inches. Going to the vertical scale and following out the level of the ordinate for 1.2 (the height of the stump), the point is located at which it intersects the abscissa for 18.2 inches; this point is found to fall within the taper curves for a 15-inch tree, breast-high. It, therefore, belongs in that diameter-class.

60. Age of Standing Trees. — To solve the second part of the problem — namely, the average age of trees of a given diameter — the ages of all trees of a given diameter-class, as determined by counts of rings on stumps, are averaged together, and the results plotted on coördinate-paper; a smooth curve is then drawn through these points, and from this curve the required relation between total age and diameter breast-high is obtained. This, in effect, yields a table from which the average age of standing trees of different diameters may be obtained. Such a table is of the greatest practical utility, since it renders possible the solution of many of the problems of management mentioned in Article 56.

61. Correlation of Age with Diameter, Height and Volume. — Age, in trees, is more closely related to diameter than to height or volume. Two trees of the same diameter may not agree at all in height or in volume; for rate of growth in height is influenced to a great extent by the fertility of the soil, and volume depends chiefly on the *form* of the tree. But even in the relation between age and diameter, there is a great lack of definiteness, or uniformity, because the density of the stand, the tolerance of the tree, and the fertility of the soil all affect the rate of growth in diameter. It may, therefore, be stated that while age is more closely related to diameter than it is to height or volume, it is impossible to do more than draw very general conclusions from such relationship. Where reliable estimates of age are required, they should be obtained by examining stumps, felled trees, or by the use of an increment borer, and should not be based upon the indefinite relation of diameter to age.

62. Age of Stands. — There are two distinct problems presented in determining the age of stands: (1) The age of a so-called "even-aged stand" may be determined with considerable accuracy, for in such a stand the trees are all of the same age, or very nearly so;* (2) the age of uneven-aged stands can be represented only as the *average* or *mean* of the ages of the several age-classes which occur in that particular stand. Where such age-classes — generally recognized as occurring in 20-year periods, as 1–20, 21–40, 41–60, etc. — are well marked, as is the case in many stands of yellow pine in the southern and western states, the problem of obtaining the average age is susceptible of at least an approximate solution. But in stands where the trees cannot be grouped into well-defined classes, the ages of which can be determined by measurement, the term "average" means but little, and in fact would have no practical application. Such stands are properly called "selection forests," through all parts of which many (or theoretically, *all*) age-classes are represented.

In the first case, the age of the class can be determined by selecting a tree of average proportions (the mean sample tree of Article 51) and ascertaining its age, either by felling it or by using the increment borer (practicable only in trees of small diameter). In the second case, where a number of age-classes are represented, the average age can be determined by making use of the familiar arithmetical formula for obtaining averages. Let a_1 be the age of class 1, a_2 the age of class 2, and a_3 the age of class 3, etc., and let N_1, N_2, N_3, etc., be the number of trees in the respective classes. Then the average age (A) of all classes can be determined by applying the following formula:

$$A = \frac{a_1N_1 + a_2N_2 + a_3N_3 + \text{etc., etc.}}{N_1 + N_2 + N_3 + \text{etc., etc.}}$$

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* According to the definition accepted in "Forest Terminology" (Soc. Am. For., 1917) differences in young stands "should not be more than 10 or 20 years; in mature stands, not more than 30 or 40 years." It will be observed, therefore, that the term "even-aged" is merely a relative term.

Example. —

$$\begin{array}{llr}
\text{Class 1, No. of trees} & 80 \times \text{age } 17 = & 1360 \\
\text{Class 2, No. of trees} & 150 \times \text{age } 35 = & 5250 \\
\text{Class 3, No. of trees} & 480 \times \text{age } 55 = & 26{,}400 \\
\text{Class 4, No. of trees} & 420 \times \text{age } 64 = & \underline{26{,}880} \\
 & & 59{,}890
\end{array}$$

$$A = \frac{(17 \times 80) + (35 \times 150) + (55 \times 480) + (64 \times 420)}{80 + 150 + 480 + 420}$$

$$= \frac{59{,}890}{1130}.$$

$A = 53$, the average age.

The practical application of the average age of stands, found according to the above formula, is limited to certain problems in forest management; it is always more or less artificial, and of more theoretical value than practical, but serves in some cases to answer, at least approximately, questions that would otherwise have to remain unanswered.

CHAPTER X

GROWTH OF INDIVIDUAL TREES

63. Importance of a Knowledge of Growth. — Growth in forest trees or stands is usually spoken of as accretion or increment, the former term being used for those quantities which are directly measurable and the latter for those quantities which must be calculated. Thus diameter and height, or length, can be measured instrumentally, and even cross-sectional area by means of tables of basal area (see Appendix, page 231), can be obtained directly when the diameter is known; but volume must be computed by the application of appropriate formulæ after certain measurements have been taken, and it is common to speak of growth in volume, whether of individual trees or of whole stands, as *increment*. The use of this term has recently become standardized * and it will, therefore, be used in the discussion that follows.

Increase in volume generally means increase in value; in the case of forest trees, the rate of increase in value often becomes accelerated towards maturity, or slightly after maturity is reached; hence a knowledge of increment has an extremely important bearing on both the financial and the technical management of the forest. (See the general subject of Rotation, in Chapter XII.) Such questions as the proper age at which to cut a stand of timber so as to secure the greatest financial returns; the choice of species for planting, — either one species alone or two or more species planted together; the length of time required to produce a given proportion of a certain size or grade of timber, and so forth; these and many other questions even more complicated can be answered satisfactorily only when the laws of growth which determine increment of forests are understood, and they affect commercial interests fully as much as they do the strictly technical interests.

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* See "Forest Terminology," Soc. Am. For., 1917. Published in "Journal of Forestry," January, 1917.

64. The Several Kinds of Increment. — Trees grow most noticeably in height. After a period of comparatively slow growth as a seedling many species of trees exhibit quite a rapid rate of height-growth in the sapling and pole stages. White pine in these stages often grows in height from 18 to 24 inches per year in favorable seasons and maintains an average of 1 foot per year over long periods. Scotch pine also grows in height with great rapidity; but the spruce and fir are not so rapid. Among the broadleaf trees, cottonwood, poplar, locust, willow, chestnut, catalpa, ash, and some of the oaks may, under favorable conditions, show extremely rapid growth in height; but much depends upon the quality of the soil and the abundance of light and moisture received.

Height-growth can be measured, as explained in Article 57, by counting the successive whorls of branches, wherever these are sufficiently distinct. But this method is practicable only in the conifers and in a few of the hardwoods which are marked by great regularity of growth. A more reliable way is to sectionize the stem at regular intervals, after which it is possible, by counting the annual rings of growth, to ascertain mathematically or graphically the rate of growth in height. This method is discussed fully in Article 65.

Diameter-growth may be studied to best advantage by making a cross-section of the stem at the desired point. It is customary to make ring-counts at the stump and at the top of each log cut by the lumbermen, from which it is possible to investigate the rate of growth at breast-height or at any other point on the stem by interpolation, or by the method already described in Article 58.

Growth in volume can be studied satisfactorily only by the method of stem analysis, described in Article 65. Growth in quality and value are, of course, quite dependent on volume, and are, therefore, susceptible of satisfactory investigation only after a detailed knowledge of volume increment has been obtained.

There remain three other special kinds of increment to be defined, namely:

Current annual increment (abbreviated to c.a.i.), which is the increase in volume, quality or value of a tree or a stand for a *specific year.*

Mean annual increment (abbreviated to m.a.i.), which is the total volume of a tree or a stand divided by its age.

Periodic annual increment, which is the increment of a tree or a stand for a specified period divided by the number of years in the period.

Since the growth for one specified year (c.a.i.) is generally very small, and is liable to fluctuations from year to year which are usually without any particular significance other than a reflection of the kind of a growing season which obtained for that year, current annual increment (c.a.i.) is generally nothing more nor less than *periodic* annual increment. It so appears in the majority of yield tables, and is frequently to be interpreted as such when met with elsewhere. In some instances the literal c.a.i. may be indicated, but the intention for such interpretation is generally stated clearly.

65. Methods of Studying Increment. — Increment may be studied by making repeated observations on the same tree (or trees) at regular intervals of years, but the objection to this method is, of course, that it takes too long to obtain results; it is used, therefore, mainly in problems where there are so many factors of uncertain or unknown influence, that it is the only reliable method which can be applied. (See Article 75.) By far the most satisfactory way to study increment is to cut the stem of the tree into a number of sections, and analyze the growth at each cross-cut. In this way, measurements can be obtained which permit the computation of the volume at any particular year, and at the same time the dimensions of the tree, both in height and in diameter, may be read directly from the data sheet, or from a graph which can be drawn very readily from the information on the data sheet. Such an analysis is called a *stem analysis,* and may be defined as the measurement of stated cross-sections of a tree to determine its increment at different periods of its life. A stem analysis may be either *partial* or *complete*, depending on whether the measurements include only a portion of the stem, or all of it.

Methods of analyzing the stem of a tree have been described in foreign textbooks * and in Bulletin 20, Forest Service, U. S. Department of Agriculture; † also in Graves' "Forest Mensuration," pages 290–293. The method to be described here is based on the same principle, but has certain mechanical advantages, tending to eliminate errors, and was made the subject of an article by one of the authors of the present volume, in 1914.‡

A felled tree should be prepared for analysis by making clean cross-cuts with a well-fitted saw, at intervals up the stem. To save expense and time, the trees cut by lumbermen on a logging operation are generally used in securing the necessary measurements; but if opportunity offers, it is preferable to have the stump-heights, log-lengths, and divisions of the bole into sections as uniform as possible. In other words, if all stumps could be cut to the uniform height of 1 foot above the ground; if all log-lengths could be 10 feet, or 12 feet; and if the top could be cut into sections of 4 feet each (suitable for cordwood), the computation of volume would not only be easier, but the results would be susceptible of more satisfactory compilation.§

For the sake of a common example, it will be assumed that an analysis is to be made of one of a number of trees just felled and cut into logs of standard length by lumbermen. To quote from the article referred to above:

On page 105 is shown a form filled in with data from a white pine, in which the usual measurements are recorded, together with a few additional ones which will render the computations in the office less liable to error. For convenience, the spaces in which the measurements are recorded are both named and lettered to correspond with the following list; and in the discussion which follows the several columns will be referred to by letter.

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* See, for example, Lorey's "Handbuch der Forstwissenschaft," 3d edit., Tübingen, 1912.

† "Measuring the Forest Crop," by A. K. Mlodziansky. Bul. 20, U. S. Forest Service (1912).

‡ Bentley, John, Jr.: "Stem Analyses," Forestry Quarterly, XII, pages 158–166 (1914).

§ See Article 36 on taper curves and Article 66 on a useful method for shortening the work of stem analyses on a large number of trees.

(*a*) The number of the section; the stump being considered No. 1, the top of the first log section No. 2, etc.
(*b*) The age of the section, *i.e.*, the age up to that section, and the number of annual rings on that section.
(*c*) The length of the section, expressed in feet and tenths.
(*d*) The diameter, outside bark, of each section, in inches and tenths.
(*e*) The diameter, inside bark, of each section, in inches and tenths.
(*f*) The width of the bark at each section.
(*g*) The width of the sapwood at each section.
(*h*) The average diameter of the several sections, by decades, as explained in the following paragraphs.
(*j*) The diameter, breast-high.
(*k*) The total age, obtained as explained in the following paragraphs.
(*l*) Clear length.
(*m*) Used length.
(*n*) Merchantable length.

It must be remembered that the object of stem analyses is to secure figures of volume growth for a given species which will enable us, after compiling a large number of values and averaging them together, to construct a table showing the average increase in volume by decades. That is, it is desired to know what the volume of White Pine, or any other species, will be, under average conditions, at an age of 10 years, and again at 20 years, 30 years, 40 years, etc. Since the age at the stump (cross-section 1) is always slightly less than the true age of the tree (from 2 to 10 years, often, depending on the stump-height, and the rate of growth of the seedling of the species), and a number of years — usually determined by a study of seedlings — has to be added arbitrarily to secure the total age of the tree, it is suggested that these years be added *before* the stem analysis is

SAMPLE FORM OF STEM ANALYSIS BLANK

No................

Locality................*Date*.................*Species* (White Pine) *D.B.H.* 21″ (*j*) *Age* 85 (*k*).

No. of section (*a*).	Age (*b*).	Length (*c*).	D.o.b. (*d*).	D.i.b. (*e*).	Width of bark (*f*).	Width of sap (*g*).	(*h*) Average diameter of sections, by decades.											
							1	2	3	4	5	6	7	8	9	10	11	Etc.
															85			
1	5+80	1.0	22.5	20.5	1.0	1.5	1.3	3.8	6.8	10.9	14.0	16.6	18.9	20.3	20.5			
2	15+70	16.2	18.1	17.3	0.4	1.5		2.4	5.8	9.2	12.0	14.6	16.2	17.1	17.3			
3	29+56	16.2	14.9	14.3	0.3	1.6			0.6	4.7	7.8	10.6	12.5	14.0	14.3			
4	37+48	12.2	12.4	11.8	0.3	1.6				1.6	5.1	7.6	9.7	11.5	11.8			
5	47+38	12.2	9.5	9.0	0.25	1.6					0.9	4.1	6.8	8.7	9.0			
6	52+33	4.0	7.8	7.4	0.2	1.5						2.6	5.3	7.1	7.4			
7	57+28	4.0	5.8	5.6	0.1	1.5						0.8	3.0	5.2	5.6			
8	64+21	4.0	4.2	4.0	0.1	1.2							1.5	3.6	4.0			
9	69+16	4.0	2.4	2.2	0.1	1.1							0.4	1.9	2.2			
(top)	85+0	7.2																
		81.0																

Clear length.................................. (*l*)
Used length.................................. (*m*)
Merchantable length.......................... (*n*)

recorded, instead of *afterward*, thereby making it possible to secure results which can ultimately be averaged together with a smaller degree of error. For example, it is known that White Pine seedlings attain an average height of one foot at an age of 5 years; a height of 2½ feet at an age of 6 years, etc.*; if the stump of the White Pine being analysed is one foot high, it is then determined that 5 years must be added to the age of the stump to secure the total age of the tree, which is entered on the blank form at (*k*), the space provided for it.

Now, as each section is analysed, the rings are counted backward from the bark to the center, beginning at the outside and designating the outermost ring with its proper number, *viz.*, *the total age of the tree*, and *not* the number of rings which happen to be found on that section. Thus, if the total number of rings at the stump is 80, and 5 years are to be added for a stump one foot high, then the outermost ring on the stump will be counted "85" and the next one inside "84," etc., counting backward, and placing a mark at the even decades, 80, 70, 60, 50, etc. In like manner, the outermost ring on all subsequent sections will be called "85," and the counting proceed backward, until the center is reached, marking each decade as before.†

In the column marked "Age" (column *b*) the age should be entered as composed of two values, the first expressing the number of years required to grow to the height of that particular section, and the second, the number of annual rings on that section.

This method of entering the age enables the reader of the form to determine the rate of height-growth very quickly, by simply glancing at columns lettered *b* and *c*, respectively.

The form, it will be noticed, is practically the same as that formerly in use. The method of entering the values under *h*, however, is quite different from that generally described in textbooks, in this respect — the measurements for all the sections at a corresponding age of the tree *fall in the same column.* That is, if the tree is 85 years old, showing 80 rings at the stump, the last measured diameter,* representing the size of that section in 1914,† will fall in column 9, and the size at 80 years of age, in column 8. This is entirely logical, for the measurements of each decade's growth fall in the column bearing the corresponding number. The measurement of the odd years, representing an *incomplete decade,* fall in the *last* column, instead of in the *first* column, as was the case in the method formerly used. If the number of annual rings at the top of the first log (Section No. 2) is 70, the age at that section will be expressed as "15 + 70," in column *b*, and the last measured diameter will be placed, not in column 7, but in column 9, directly under the corresponding measurement for section 1. Similarly, the measurements for the last section, although it shows only 15 annual rings, will be entered so that the diameter of the stem at that point in the year 1914 will fall in column 9. To find the volume of the tree in the year 1914, the dimensions of the several sections are read directly from column 9, where they appear one under the other in their logical order. There is now no chance of selecting the wrong pairs of values in computing the volumes of the several sections, and no chance for errors in doubling the radii, for diameters have been recorded directly. It would appear that one of the great stumbling-blocks in computing volumes from stem analyses could thus be removed by tabulating the data in the manner described. The advantages of recording the data and measurements in this form are obvious, and at the same time the whole arrangement is much more logical, since the measurements for any particular decade all fall in the same column.

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* Values are taken from U. S. Forest Service Bulletin 22, "The White Pine," by V. M. Spalding and B. E. Fernow, page 28.

† If it is preferred by some to count from the center outward, the number of rings on the section can be subtracted from the total age, and the counting begun at the age obtained. For example, on section 5 there are 38 annual rings; this subtracted from 85 = 47, and the counting may begin at the pith (center), counting "48," "49," "50," etc., and a mark placed on the even decades, 50, 60, etc. This accomplishes precisely the same result, and obviates the necessity of counting backward, which may be objectionable to some.

Having made and recorded a complete stem analysis as described, it is now possible to compute the volume of the tree at the age of 10 years, 20 years, 30 years, etc., for as many decades as may be needed in the investigation under way. The volume is generally calculated in terms of cubic feet, and the formulæ used, which are applied to the several sections of the tree, have already been described in Article 25. Unless great precision is required, the logs of a tree are usually considered as frustums of paraboloids, the stump as a cylinder, and the top is regarded as a cone. For convenience in these computations, tables of basal areas, in which the areas of circles are given in terms of *square feet*, are included in most books on Forest Mensuration. See Appendix, page 231, for such a table.

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* Diameters are recorded instead of radii.

† The year the measurement was made.

66. Stem Analysis as applied to a Large Number of Trees. — It is a very laborious piece of work to make all the measurements and computations of volume called for in a complete stem analysis, particularly if the tree be of great age and of large size. When a large number of trees are to be analyzed, the amount of work involved is often too great for economy, and it therefore becomes advisable to shorten the computations as much as possible. This can be done to best advantage when the trees are all sectionized at the same heights above the ground, as suggested on page 103. Under these conditions, a method has been described which requires just as many field measurements, but the work of computation is reduced to a minimum.* This method consists in averaging together the measurements of diameter-growth made at certain specified heights above ground on trees belonging to the same crown-class, from which curves are drawn which show the average growth in diameter, by decades, at each of the specified levels. From these curves, the dimensions of an ideal tree (the average for the class) are determined, and the volume of this ideal tree computed. In other words, the measurements of diameter are averaged together, and *one volume computation* made for all trees of a class, instead of averaging together the computed volumes for all the trees of that class. Since the most laborious and time-consuming part of the work of stem analyses consists in the mathematical calculations which must be made, anything which eliminates a large part of this work effects a big saving in time and cost.

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* See U. S. Dept. Agr. Forest Service Bul. 20, "Measuring the Forest Crop," by Mlodziansky, A.K.; and Graves, H. S.: "Forest Mensuration," pages 294–298.

A further shortening of this kind of work can be effected by combining the average diameter-growth curves for the several sections of the trees on one single sheet of coördinate paper, as described by Graves.* This affords a graphic representation of the rate of growth of a class of trees which answers many questions at a glance, besides lending itself admirably to the reduction of the computations necessary for volume studies. The dimensions of the average tree can be read off the curves, and the computations of volume can then be made once for the entire group or class.

67. Increment Per Cent. — A very convenient way in which to express increment is in terms of percentage. To the average business man, the statement that a pure stand of red pine at 35 years of age is growing at the rate of 1½ per cent per year is likely to mean more than to tell him that it is increasing in volume at the rate of 40 cubic feet per acre per year. Unless he happens to be familiar with the increment and yield of red pine, the figures would probably mean little or nothing to him. But practically all people can understand increment if it is expressed in terms of percentage; hence the usefulness of formulæ which express increment in such terms.

The most accurate way to express increment per cent is to consider the volume of the tree at a specified year as the Base, or the Principal; the current annual increment, or the periodic annual increment as determined usually for a short period of years (corresponding to the interest on the Principal for one year), is then divided by the Principal, and the result is the Rate per cent. The method of arriving at this rate per cent may be explained as follows:

Let V = the present volume of a tree,
v = the volume n years ago.
Then $V - v$ = the increment for n years,
and $\frac{V - v}{n}$ = the increment for *one* year †
and let p = the rate per cent.

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* Graves, H. S.: "Forest Mensuration," page 295.

† Although this is, strictly speaking, the *periodic annual increment*, it is frequently regarded as the *current annual increment*. See definitions, and explanation of this apparent inconsistency on page 102.

Then, depending on whether V or v be considered the ***base***, or ***principal***, two formulæ are developed as follows:

$$V : \frac{V - v}{n} = 100 : p,$$

$$pV = 100\left(\frac{V - v}{n}\right),$$

whence

$$p = 100\left(\frac{V - v}{Vn}\right), \qquad (1)$$

$$v : \frac{V - v}{n} = 100 : p,$$

$$pv = 100\left(\frac{V - v}{n}\right),$$

whence

$$p = 100\left(\frac{V - v}{vn}\right) \qquad (2)$$

Difference of opinion as to which of these two formulæ is to be preferred, led to the derivation of a third described in the next article.

68. Pressler's Formula. — Since it might be argued that either V or v could be used as the base (although in most interest calculations, it would be customary to regard v as the principal) Pressler [*] developed a formula in which the *mean* of the two quantities, V and v, is used as follows:

$$\frac{V + v}{2} : \frac{V - v}{n} = 100 : p,$$

whence

$$p = \left(\frac{V - v}{V + v}\right)\frac{200}{n}. \qquad (3)$$

As a matter of fact, this formula (3) is regarded as yielding the most satisfactory results. If the length of time required to grow from one inch-class (d.b.h.) to the next above it be known, then the figures in any carefully constructed, reliable volume table may be used for the corresponding values of V and v, respectively, in a practical application.

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[*] M. R. Pressler, 1815–1886. Contributed largely to that part of forestry dealing with mathematics.

69. Schneider's Formula. — By an ingenious application of the formula for the volume of a tree in which the form factor F is used * Schneider developed a formula which is extremely simple, and gives fairly good results when applied to trees in which the height-growth is practically at a stand-still, *i.e.*, in *mature trees*. The formula is as follows:

$$p = \frac{400}{nD},$$

in which

n = the number of rings in the last inch of the radius, at breast-height,
D = the present diameter of the tree,

and

p = the volume increment per cent.

The number of rings in the last inch of radius can be ascertained most conveniently by using an increment-borer (see Article 18) on trees the wood of which is soft enough to permit its use. On hardwoods, it would be necessary to make an incision such that the annual rings of growth could be counted and measured on a surface perpendicular to the stem of the tree.

Where the trees are not mature, and where height-growth is still progressing at a moderate rate, better results can be obtained if instead of 400, the quantity 500 is used as the numerator of the fraction; and in cases of very vigorous height-growth, a numerator of 600 gives approximately correct results. It should be distinctly understood, however, that in no case can Schneider's formula be depended upon to give such satisfactory results as Pressler's; it finds its legitimate use as a short, easily applied formula, giving results only roughly approximate, but sufficiently accurate for preliminary estimates of increment. In its modified form, it is still less to be relied upon.

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* See Article 31 for the application of form factors.

CHAPTER XI

INCREMENT OF STANDS

70. Increment in Stands. — The study of increment in individual trees presents a number of problems, as has been shown in the preceding chapter; increment in whole stands is even more complex, for to the difficulties already encountered in the problem for single trees there must be added the ever-changing character of the stand, especially as to the *number* and the *sizes* of the trees composing it. If the stand be pure and even-aged, then the problem is presented in its simplest terms and it can be solved as described in subsequent paragraphs (see Article 72). The introduction of a number of different age-classes complicates the problem to such an extent that no very definite conclusions can be drawn; while if stands are both *uneven-aged and mixed* (*i.e.*, composed of more than one species) there is little that can be done except by the method of permanent sample plots as described in Article 74. But the obstacles in the way need not deter us from *investigating* the problems; and if we can but secure a good idea of the general *rate* of volume increment in stands, it will be a great help in attacking some of the questions of Forest Management.

The more important of these problems of increment may be stated broadly as follows:

(1) *Increment in Pure, Even-aged Stands.* — Increment in stands of this character is best studied by laying out a large number of plots and measuring the trees thereon. From these measurements, yield tables are constructed. Yield tables are defined in Article 71 and the method of constructing them for pure, even-aged stands is described in Article 72.

(2) *Increment in Pure, Many-aged Stands.* — Increment in many-aged stands may also be investigated by laying out a number of plots, but the method differs in several respects from

that just referred to, especially when the stand is of open character. The results of the investigation may be combined in a so-called yield table, but special emphasis is placed upon the determination of the current annual increment and the mean annual increment. One of the methods employed in solving this problem is outlined in Article 73.

(3) *Increment in Mixed Stands of the Selection Form.** — Increment in stands of this character may be investigated in a more or less approximate manner by any one of several methods which have been evolved and elaborated by some foresters who possess a mathematical turn of mind and a lively imagination; but they all make use of measurements made at *one* point (or at most, only two or three points) in the life-history of the stand — usually the present — and attempt to predict future increment in this stand when the composition of it and the rate of increment in the several species are changing so as to render such predictions nothing more than conjectural. In other words, there are so many factors entering into the problem, — some of which are little known or understood and others of which are not susceptible of exact measurement, — that it is practically impossible to solve it except by the empirical method, requiring a long period of years. (See Article 75.)

Since these problems differ considerably, they must be investigated by methods appropriate to the objects sought, and they will be discussed separately in Articles 72, 73, and 74. First, however, it will be advisable to take up the general subject of Yield Tables, for the main object in the investigation of yield is to gather data which can be assembled and tabulated for ready reference in the work of Forest Management.

71. Yield Tables. — A tabular statement of the periodic yields attainable at different ages (usually in 10-year periods) per unit of area (usually the acre) is called a yield table. Such tables are constructed separately for given species, on different sites, under specified systems of treatment, and are used as standards with which to compare *actual* yields.

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* A stand is said to be of the selection form when many or, theoretically, all age-classes are represented, irregularly scattered through the stand.

A complete yield table contains a great deal of information, and is made to show the following data: *

(1) Age. (By decades, from 10 or 20 to 100 or more, depending on species.)

(2) Number of trees per unit area. (Acre in U. S.)

(3) Basal area in square feet.

(4) Diameter breast-high of the average tree.

(5) Height of average tree

(6) Form factors (for the forest).

(7) Yield, { (*a*) Intermediate yields.
  (*b*) Total yield.

(8) Current Annual Increment (c.a.i)

(9) Mean Annual Increment (m.a.i.)

(10) Supplementary to items numbered (7), (8), and (9), there is often a subdivision of the total yield into (*a*) merchantable saw-timber, and (*b*) fuel wood.

Yield tables thus far prepared in this country are relatively simple when compared with European tables, the data appearing in items numbered (6), (7)(*a*), and (10) are often omitted, and the table assumes a comparatively simple form.

The chief uses of yield tables are (1) to determine the approximate final yield of a stand of timber at any given rotation age, when the quality of the site is known; and conversely (2) to determine the quality of site occupied by a stand, when the volume per acre, age, and the density (judged by basal area) are known; (3) to make comparisons between the actual c.a.i. or m.a.i. of a given stand and the normal increments as shown in the table; (4) to estimate the volume of a stand, knowing its age and density (basal area), etc., etc.

Since yield tables represent *ideal conditions* which are rarely if ever fulfilled over areas of any extent, it is generally necessary to apply a reducing factor to the quantities as given in the table. The ratio between the actual and the normal may be determined approximately by comparing the basal area of the actual stand with the basal area of the normal stand as given in the table; for it has been found that the basal area is a very good index of the relative volumes. For example, if the basal area of a 50-year-old stand of white pine, on quality II site, is given in a reliable yield table as 232 square feet, and a stand under investigation, of the same age and on the same quality of soil, is found to have a basal area of only 190 square feet, then the volumes may be expected to show approximately the same relation, or

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* Arrangement of the Tables is generally in vertical columns, reading across the page opposite the several age-classes, which appear as the extreme left-hand column. See example of yield table in the Appendix, page 234.

$$\frac{\text{volume of actual}}{\text{volume of normal}} = \frac{190}{232} = 0.82.$$

72. Construction of Yield Tables for Pure, Even-aged Stands. — This problem is the least difficult of any, and will, therefore, be described first. The work consists of measurements in the field and computations in the office, and the following steps may be recognized:

(1) Select a number of pure, even-aged stands representing as many different ages and site qualities as possible. The number of plots should be as large as possible consistent with the amount of money available for the study and may be anywhere from 30 to several hundred. Most yield tables show data for at least 10 age-classes, by intervals of 10 years from 20 to 110 or more,* and since at least three different qualities of site should be recognized, this means that *at least* 30 *stands* should be selected in which conditions of growth are as uniform and even as possible. The stands in each instance should be fully stocked (*i.e.*, there should be no open spaces, but the crowns of the trees composing the stand should touch one another) and they should also be normal,† so far as can be judged.

(2) In each stand, lay out a plot, either square or rectangular, and number it. The plots should be one acre in area if possible, but if plots of 0.5 acre (or even 0.1 acre in young stands) can be found where the conditions are quite uniform, they are to be preferred to larger plots which do not exhibit the desired degree of uniformity.

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* See example of Yield Table in Appendix, page 234.

† For an explanation of this term, see Chapter XII.

(3) Measure the diameter breast-high of all trees within the plot. (On plots of young trees, 2 inches may be taken as the minimum diameter.) Record these by diameter-classes of individual inches. Ascertain also the average height of the stand, with the aid of the hypsometer.

Determine the *mean sample tree*, by the method explained in Article 51 and fell at least three such trees on the plot which shall be normal, representative trees, and which fulfil the requirements as to average diameter and height.

(4) Make complete stem analyses of these trees, if possible; or if time does not permit this, determine at least the exact volume, age, and rate per cent of the increment for the last decade. Then apply the method of the mean sample tree to determine the volume of the entire stand, in cubic feet. The cubic foot is used as being more applicable to young stands, and as being more truly indicative of the actual increment taking place. (See Article 9.)

(5) If some of the plots have been other than 1.0 acre in area, reduce all the figures of volume to terms of 1.0 acre.

(6) Taking a sheet of coördinate paper, with age as the horizontal scale (abscissæ) and volume as the vertical scale (ordinates), plot the volume of each sample plot, and identify it with its appropriate plot number.

(7) If in the selection of stands, wide ranges in age and in quality of site have been observed, it should now be possible to draw a *maximum* volume curve and a *minimum* volume curve, representing the extremes. Any values which seem to be abnormal, by reason of their marked departure from the general average should be discarded, and omitted from the calculations. Depending on the number of site qualities * to be recognized, intermediate curves should be drawn, which will harmonize with the maximum and minimum curves, and which will make the breadth of the "bands" resulting approximately equal for a given age. (See Fig. 21.) The bands now show graphically the division into site quality, and those plots (by number) which

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* In the United States it is customary to recognize three qualities, designated I, II, III.

are found situated in the uppermost band will belong to Quality I (best); those in the lowest band will be classed as Quality III (poorest); and those in the intermediate band will be classed as Quality II (medium). Three curves may now be drawn, one in the *center of each band*, which will represent the *average* for the particular band in which it appears.

(8) The last step is to tabulate the figures read from the curves in the *center* of the bands, as just described, one table being prepared for each site quality separately as shown in the sample form of yield table in the Appendix, page 234.

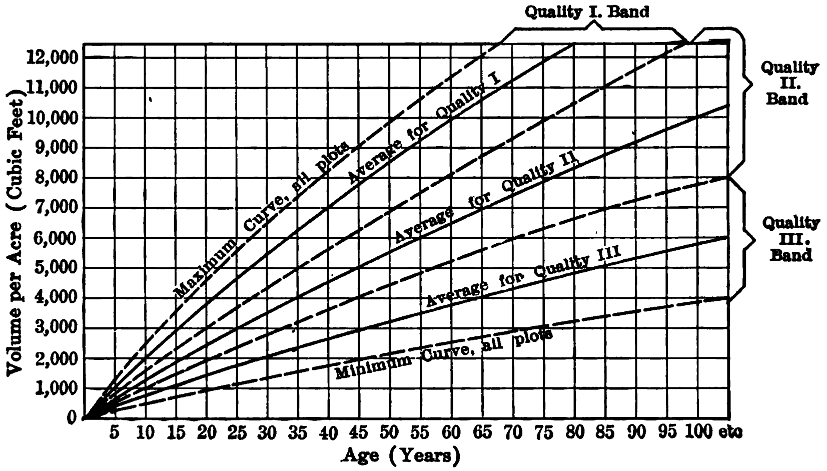

FIG. 21. Diagram to Illustrate the "Band" Method of Determining Site Quality.

The yield table now brings together in convenient, usable form the results of the investigations, and is an indispensable help in the solution of the various problems of forest management.

73. Construction of Yield Tables for Uneven-aged Stands. — It must be quite apparent from the foregoing discussion that the three great essentials in any study of yield are a knowledge of *volume*, *area*, and *age*. In other words, what is desired is a statement of the volume per acre at a given age, in fully stocked stands which are growing on forest soils of Quality I, Quality II, and Quality III. The problem presented by uneven-aged stands is not easy of solution, and since the results are generally compiled in the form of a table similar to tables for even-aged stands, it should be explained and understood that the *application* of these tables cannot be *direct*. The tables are useful, however, in that they show the rates of the increments (both current annual increment and mean annual increment), which are so necessary in deciding questions of policy in management. The problem has been studied by a number of foresters of this country, with the result that many papers have been published in the technical journals.* The essential steps in the process, as worked out by some of these authors, are as follows:

1. Select pure stands as nearly fully stocked as possible, and representing conditions typical of the region. The degree to which the stands are stocked (*i.e.*, the *density* of the stands) will vary a great deal according to the species of tree, the climatic conditions, and the soil quality; and great care should be exercised to keep separate and distinct the stands which represent the three site-qualities.

2. In these stands, lay out plots, or run strips, on which trees of all sizes from two inches up are calipered. The tally of trees generally should be by individual inch-classes, although in some of the methods used, certain broader classes are also made use of. Depending on conditions, the plots may be anywhere from 1 or

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* See especially articles by the following authors, who have contributed largely to our present knowledge of the subject:

(1) Chapman, H. H.: "A Method of Investigating Yields per Acre in Many-aged Stands," For. Quart., Vol. 10, page 458.

(2) Chapman, H. H.: "The Measurement of Increment on All-aged Stands," Proc., Soc., Am. For., Vol. 9, page 189.

(3) Carter, E. E.: "The Use of Yield Tables in Predicting Growth," Proc. Soc. Am. For., Vol. 9, page 177.

(4) Moore, B.: "Yield in Uneven-aged Stands," Proc. Soc. Am. For., Vol. 9, page 216.

(5) Woolsey, T. S., Jr.: "Yield Table Method for Arizona and New Mexico," Proc. Soc. Am. For., Vol. 9, page 207.

(6) Ashe, W. W.: "Determination of Stocking in Uneven-aged Stands," Proc. Soc. Am. For., Vol. 9, page 204.

(7) Munger, T. T.: "A Formula for Normal Growing Stock in Selection-System Forests," Proc. Soc. Am. For., Vol. 10, page 18.

(8) Morrill, W. J.: "Method for Regulating the Yield in Selection Forests," For. Quart., Vol. 11, page 21.

2 acres up to 20, or even 40 acres, the larger sizes being employed only in stands of open character, such as Western yellow pine in the Southwest. The seedlings and saplings are usually studied intensively on small plots (0.01 acre to 1.0 acre) located within the large ones. Under certain conditions, the tally-sheets of regular timber-cruises may be used, provided the site-qualities can be distinguished with a fair degree of precision. This work enables the preparation of *stand tables* for each of the forest types and site qualities. These are to be used in step number 6(*c*).

3. Next, make a study of the *crowns* of the trees of the several size-classes, with the object of determining just how much growing space is required for a tree of a given size-class. Moore (see reference number 4 on page 118) recommends the following method of procedure for this step:

"Crown measurements may be made in one of two ways: (*a*) One man stands off from the tree, where he can see both sides of the crown; he then lines in the second man under one edge of the crown, has him measure across under the crown at right angles to his (the first man's) line of sight, then stops him under the far side of the crown. The measurer calls out the distance, and the first man records it opposite the proper diameter, which has already been measured and recorded. (*b*) Each man works alone, lining himself in under one side, measuring across under the crown, and then lining himself in under the other side. This is, I believe, less accurate than the first method, unless the men have previously practiced lining each other in as under (*a*), but is more rapid, especially where two diameters are required for most trees."

Moore recommends measuring about 20 trees in each diameter-class, representing all crown-classes of trees and keeping the records distinct for the different site-classes.

4. The crown area may be computed by squaring the diameter of the crown. This gives more than the true crown area (area of circle = $0.7854 D^2$), but the crowns do not touch on all sides, and by squaring the diameter, the author believes results are obtained which agree more closely with conditions as they

actually exist. The results are plotted on cross-section paper, the crown areas being the vertical scale, and diameter-classes (d.b.h.) being the horizontal scale; a curve is drawn which is at least a good index of the *relative growing space* required by each diameter-class, if not the *actual growing* space.

5. The average rate of growth in diameter is obtained from about 100 stump counts of each species, for each type and site quality represented. This work may be done as described in Article 60. The average age of trees of each diameter is wanted, therefore the points for the curve should be balanced horizontally, if such balancing is necessary.

6. Considering each *diameter-class* as an *age-class*, the following computations should next be made:

(*a*) *Volume:* Apply appropriate volume tables, using cubic feet as the unit wherever possible.

(*b*) *Age:* The average age for the diameter-class can be obtained from the curves drawn as described under step No. 5.

(*c*) *Area:* The area occupied by each age-class (= diameter-class) can be computed by obtaining the product of the number of trees as shown in the stand table (step No. 2) multiplied by the crown area of the class, as shown by the curve obtained in step No. 4.

7. Convert the volume for each size-class, as found by the process described under 6(*a*), to the basis of *one acre*, by dividing by the area (decimal part of an acre) as determined under 6(*c*). This now gives the data necessary for the final step.

8. Construct a simple yield table by plotting on cross-section paper the *volume per acre* as found in step No. 7 on the average *age* as found in step No. 5. A smooth curve should be drawn through the points obtained from which may be read the volumes at even 10-year intervals, thus giving a part of the data required for a complete yield table. The table may be completed by making calculations to show number of trees per acre, basal area per acre, the mean annual increment, and the current annual increment.

The method as described above is not without its weak points, and in the application of the results it is quite essential to keep in mind the limitations and the shortcomings of the method. Some of the difficulties are as follows:

(1) The table represents conditions as they might occur in fully stocked, even-aged stands. As a matter of fact the actual stands are rarely fully stocked, and are not even-aged. The climate, the soil conditions, the site factors, and indeed the inherent silvical character of the species may combine to make a fully stocked stand impossible in fact. In interpreting the table, therefore, these points should be borne in mind.

(2) The method of using crown area to determine the factor of area is not always safe. In very old, decadent trees the crown is quite likely to be smaller than it was at the time of the tree's best growth, and hence the space at present occupied is not a true indication of how much space *has been* occupied in the past, to accomplish the growth. In very young trees a similar difficulty is encountered, inasmuch as seedlings and saplings may grow for a time *under the shade* of the older trees,* and hence the same space (crown area, as projected on the surface of the ground) may be occupied by the two classes of trees — the mature and the immature. This naturally leads to what would appear to be an abnormal *over-crowding;* but in uneven-aged stands of tolerant species, this condition may be perfectly normal.

With slight modifications as to details, other writers have described methods of studying increment in uneven-aged stands which are similar to the foregoing. The age-classes recognized may be broader than individual inch-classes, and the method of determining the *area* occupied by each age-class may be modified to suit special conditions; but in one way or another any method, to be at all useful, must take account of the three factors already mentioned — age, volume, and area.

74. The Study of Increment in Mixed Stands. — When a stand is composed of a number of species growing together indiscriminately, it is impossible to construct a yield table which is such in the true sense of the term as already defined. The proportionate representation of species in the mixture is constantly changing because of differences in *tolerance*, differences in *rate of growth*, and differences in *reaction to the physical factors* of site. Moreover, the same species may exhibit a behavior in one mixture totally different from its behavior in another mixture. The problem is so complicated that the only thing that can be done is to make repeated observations on selected areas at definite intervals of time, recording with great care the measurements and descriptions of the stand for future comparisons. Studies of this kind are best made by establishing permanent sample plots, which are the subject of the next article.

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* Trees that are capable of growing under more or less shade are spoken of as "tolerant"; those that cannot endure shade are spoken of as "intolerant."

75. Permanent Sample Plots. — The establishment and study of sample plots in Europe was begun about sixty years ago, but in this country no effort was made to establish permanent plots until 1904, when the then Bureau of Forestry initiated such a policy. The purposes of permanent sample plots are to afford opportunities to study increment in trees and stands, and to observe the effects of applying certain definite systems of silvicultural practice.* The effects of thinnings, cuttings, fires, grazing by animals, etc., may be observed in sample plots — in short, the effect of all influences combined can be observed and interpreted in the light of the known history of the stand, as disclosed by the records.

Depending on the density of the stand and the specific objects of the investigation, permanent sample plots may be from a square rod up to several acres in area. For purposes of investigating increment and yield, plots are generally of 1 acre or one-half acre in dense stands, but may be as much as 5 acres, 10 acres, or even 40 acres in very open stands. Each tree on the plot receives a serial number, and its diameter is carefully measured at a definite point. Since painted numbers are likely to weather off, numbers may be stamped on copper or zinc tags, and these attached to the tree by nails. If care is exercised to drive the nails at exactly breast-height, and if the diameter is measured with a circumference tape, it will be possible to remeasure the trees on the plots at intervals of 5 or 10 years with the positive assurance that the re-measurement is being made at precisely the same spot as was the original measurement — a matter of the highest importance.

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* See Graves, H. S.: "Forest Mensuration," N. Y., John Wiley & Sons, Inc., 1906, page 345.

Sterrett, W. D.: "Objects and Methods of Establishing Permanent Sample Plots," Proc. Soc. Am. For., II (1907), page 63.

Munger, T. T.: "Five Years' Growth on Douglas Fir Sample Plots," Proc. Soc. Am. For., X (1915), page 423.

Besides numbering and measuring the diameter of all trees on the plot, a number of representative trees are measured as to *height* and *crown* development; very careful descriptions are written; and numerous photographs are taken from designated spots, so that the changes taking place can be photographed and compared at leisure, at any time in the future. While the lapse of a long period of years is necessary before any definite information can be obtained, this method of permanent sample plots is the only reliable one, when increment in mixed stands composed of trees of all ages is being investigated. By establishing plots in well-defined forest types in many localities, and conducting the work according to a definite plan of operations, there will gradually become available a mass of information concerning the life-history, development, and increment in mixed stands of all ages, which will be invaluable to foresters and lumbermen in solving the intricate problems of forest management. It is gratifying to know that such studies are being made,* and that in the course of time reliable statistics of increment in stands of the selection form will be available.

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* See Woolsey, T. S., Jr.: "Permanent Sample Plots," For. Quart., Vol. X, No. 1, pp. 38–44. "Plan for Permanent Sample Plots in the Adirondacks," Jour. For., Vol. XVI, No. 8, pp. 922–927.

CHAPTER XII

FOREST ORGANIZATION

76. Definition. — *Forest organization* concerns itself with the organization of a forest property for management and its maintenance, ordering in time and place the most advantageous use of the property, with the ultimate aim of securing a sustained yield. The term *forest regulation* covers the same idea, but, since it suggests police and administrative prescriptions, seems less desirable except for that part of organizing a forest which concerns itself with regulating the cut.

In order to have a definite scheme for the conduct of operations on a tract so as to secure most effectively the objects desired by the owner, a *working plan* is formulated. This may be defined as the plan or plans under which a given forest property is to be continuously managed.

77. Sustained Yield. — By sustained yield is understood the yield or cut of timber from a forest which is managed in such a way as to permit the removal of an approximately equal volume of timber, annually or periodically, equal to the increment. (See Chapter XI.)

The five requisites for a sustained yield management are:

1. Enough, accessible forest.
2. A forest of the right character so that it will pay to cut it for repeated crops.
3. Adequate fire protection.
4. Equitable taxation.
5. Good markets for products.

Wherever these conditions obtain, intensive forestry is practicable.

78. The Normal Forest. — The normal forest is a standard with which to compare an actual forest to bring out its deficiencies for sustained yield management; the conception of an ideally regulated or organized forest. The term "normal" is here used in the sense of conforming to a standard, rule, or principle — a model. Such a forest does not actually exist anywhere.

The normal forest has three attributes: *normal increment*, *normal age-classes* in size and distribution, and *normal growing stock*.

(1) By *normal increment* is understood the best average increment attainable by given species on given sites.

(2) To understand *normal age-classes* requires first an explanation of what is meant by an age-class. All the trees in a stand or forest whose age falls within stated limits are spoken of as being in the same *age-class*. Age-classes are usually divided into twenty year periods, so that a stand in which the trees fall between the age of 1 to 20 years would be referred to as Age-Class I. Age-classes are stated in extent of area or in percentage of the whole stand, or, in selection forest (that is, a forest through all parts of which many different age-classes are represented) by number of trees.

Distribution of age-classes refers to either the local distribution of age-classes or to the percentic or absolute representation of the different age-classes in area or amount, or (in selection forest) in number of trees.

Normal age-class distribution in the strict sense of actual location, means such distribution of the age-classes as will permit annual or periodic fellings to be made without damage to adjoining stands. In the broader sense of extent of area or amount, it means that each age-class is equally represented in per cent or in absolute area, that is, the presence of a complete series of age-classes corresponding to the rotation. It is in this latter sense that the term is usually used in describing the normal forest.

(3) The third and last attribute of the normal forest, *normal growing stock*, means the amount of material represented by the stands in a normal forest.*

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* Practically, it is the contents of the normal age-classes as represented in *normal yield tables* (see Chapter XI). The statements of a normal yield table are derived as an average from the best producing, fully stocked areas for given species and sites. If a normal forest were not merely an idea, but actually attainable, the normal yield table would represent its productivity and growing stock.

Normality in (1) and (2) always results in normality in (3), but the reverse is by no means true. A normal growing stock may exist in a forest with only a single age-class, as is shown in Fig. 22.

Nevertheless, as Flury says,* "the normal growing stock is the best, most pregnant, numerical expression of sustained yield management. To attempt an approach to normal stock conditions in some way, must be the aim of the manager for sustained yield."

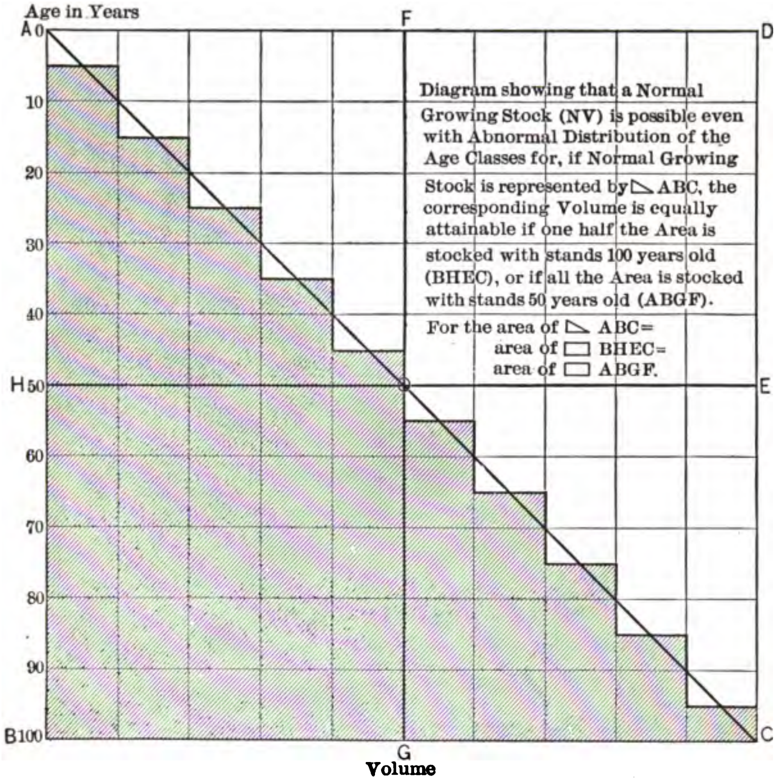
Age in Years
A 0
F
D
10
20
30
40
H 50
E
60
70
80
90
B 100
C
G
Volume
Diagram showing that a Normal Growing Stock (NV) is possible even with Abnormal Distribution of the Age Classes for, if Normal Growing Stock is represented by ◺ ABC, the corresponding Volume is equally attainable if one half the Area is stocked with stands 100 years old (BHEC), or if all the Area is stocked with stands 50 years old (ABGF).
For the area of ◺ ABC=
area of ▭ BHEC=
area of ▭ ABGF.

FIG. 22.

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* "Grösse und Aufbau des Normalvorrates im Hochwalde," Mitteilungen der Schweiz. Centralanstalt für das Forstliche Versuchswesen, XI, 1, 1914, pages 97–148.

The actual growing stock is the volume of material which is present on a given forest. This is obtained by timber estimating (see Chapter VIII). But how can the normal growing stock be determined?

79. Determination of the Normal Growing Stock. — The normal growing stock (NV) is obtained (1) by formula (2) from yield tables.

(1) The normal growing stock is expressed by the formula $NV = \frac{ri}{2}$ where NV = normal volume of growing stock, r = rotation, and i = the mean annual increment.

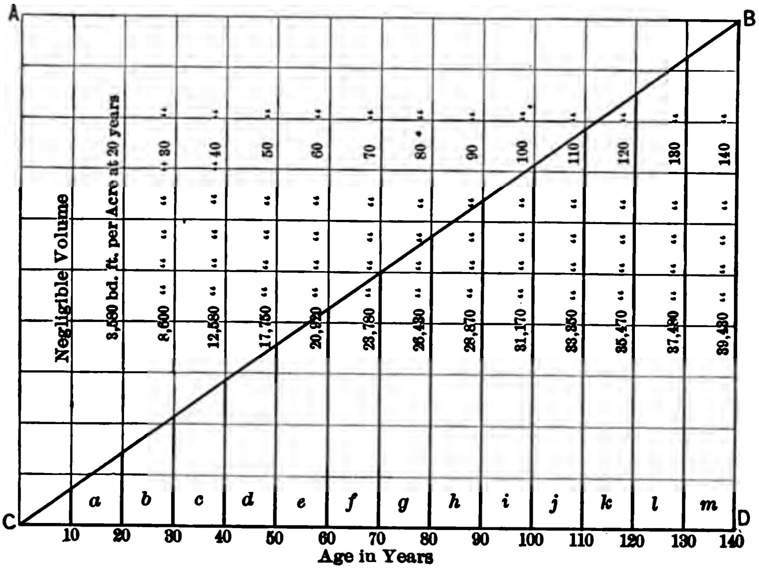

FIG. 23.

(2) NV can also be determined directly from yield tables constructed by measurements of fully stocked stands.

NV then equals $N\left(a + b + c \cdots + \frac{M}{2}\right)$ where N = number of years in each age-class (step of the yield table) and $a, b, c, \ldots M$ = the volume per acre given in the table for each age-class.

The method and correctness of finding NV (1) by formula, (2) by summation from yield table, is illustrated in Fig. 23. For the values as given in this diagram, which is based on a yield table for white pine constructed by W. J. McCarthy, M.F., in the vicinity of Ithaca, N. Y., the normal growing stock would be as follows, assuming a forest of 1000 acres:

(1) $NV = \frac{ri}{2}$. r = rotation = 140 years,

i = mean annual increment per acre = 281.64 board feet.

$$NV = \frac{140 \times 281.64}{2} = 19{,}715.$$

$$19{,}715 \times 1000 = 19{,}715{,}000 \text{ board feet.}$$

(2) $NV = N\left(a + b + c \cdots + \frac{M}{2}\right)$.

N = number of years in each step of yield table = 10. $a, b, c, \ldots$ are volumes per acre in each step of yield table. M is volume per acre at the rotation age (140 years).

$$NV = 10\left(3580 + 8600 + 12{,}580 \cdots + \frac{39{,}430}{2}\right)$$

$$= 2{,}996{,}950 \times \frac{1000}{140 \text{ yrs.}} = \frac{2{,}996{,}950{,}000}{140} = 21{,}407{,}000$$

board feet.

Many authors have busied themselves with the problem of how to determine the normal growing stock most accurately and have suggested certain departures. Thus Flury * claims that the formula $NV = \frac{ri}{2}$ to be more generally correct should read: $NV = c \times r \times i$ in which c is a variable constant. To determine this constant, normal yield tables are necessary which may be summed up by the formula

$$NV = N\left(a + b + c \cdots + \frac{M}{2}\right) = S,$$

then since

$$c \times r \times i = S,$$

$$c = \frac{S}{r \times i}.$$

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* "Schweizerische Zeitschrift für Forstwesen;" March, 1913, briefed For. Quart., Vol. XIII, No. 1, pages 108–113.

Applying Flury's constant C to McCarthy's white pine yields as given above, the factor is as follows: for rotation of 30 years, $C = 0.306$; for 40 years, 0.365; for 50 years, 0.378; for 60 years, 0.421; for 70 years, 0.452; for 80 years, 0.475; for 90 years, 0.493; for 100 years, 0.507; for 110 years, 0.518; for 120 years, 0.525; for 130 years, 0.536; and for 140 years, 0.542.

Thus the value for 140 years given above as 19,715,000 board feet would be corrected as follows:

$$NV = c \times r \times i = 0.542 \times 140 \times 281.64$$
$$= 0.542 \times 39{,}430 \times 1000 \text{ (acres)} = 21{,}371{,}000 \text{ board feet.}$$

which compares closely with the value 21,407,000 board feet found by summation of the yield table.

It is obvious that where the constant C is approximately 0.5 the error in finding NV by the formula method is least, since $NV = \frac{ri}{2} = 0.5 \times r \times i$.

To further illustrate the workings of C the average value of C has been found by and applied to the white pine yields as given in table 6, Bulletin 13, U. S. Dept. of Agriculture, for site quality II, *i.e.*, medium site quality. The values by formula, with and without use of C and by summation of yield table, are also given.

AVERAGE VALUE OF CONSTANT C IN WHITE PINE, SITE QUALITY II, BASED ON TABLE 6, U. S. DEPT. OF AGRIC., BUL. 13.

Rotation (years).	C.	$NV = \frac{ri}{2}$.	$NV = N\left(a + b + c \cdots + \frac{M}{2}\right)$.	$NV = c \times r \times i$.	Difference between last 2 columns.
			Feet, Board measure, per acre.		
40	0.227	11,750	5,337.5	5,334.5	3
50	0.280	18,300	10,280	10,248	32
60	0.330	23,450	15,525	15,477	48
70	0.368	28,050	20,764	20,644	120
80	0.399	32,000	25,588	25,536	52
90	0.426	35,430	30,239	30,203	36
100	0.449	38,500	34,610	34,573	37
110	0.465	41,600	38,745	38,771	26
120	0.484	44,050	42,654	42,650	4
130	0.506	45,750	46,280	46,299	19
140	0.549	47,050	51,604	51,660	56
				Ave.......	39.4

NOTE. — Values over 100 years from prolonged curves.

Munger* has devised a formula for determining normal growing stock in selection forests. Munger conceives of the normal growing stock as consisting of the reserve left after cutting multiplied by the area, plus one-half the growth which takes place on the entire forest for the entire cutting cycle. Expressed as a formula:

$$NV = \frac{i \times cc}{2} + \text{reserve for the entire forest,}$$

where i = the current annual increment on the entire forest and cc = the cutting cycle (interval between cuts).

Example. — If for 50 acres $i = 5000$ board feet, $cc = 50$ years, that is, one-quarter of the 200-year rotation, and reserve = 200,000 board feet, then,

$$\begin{aligned} NV &= \frac{i \times cc}{2} + \text{reserve} \\ &= \frac{5000 \times 50}{2} + 200{,}000 \\ &= \frac{250{,}000}{2} + 200{,}000 \\ &= 325{,}000 \text{ board feet for the entire fifty acres} \\ &= 6500 \text{ board feet per average acre.} \end{aligned}$$

Using the formula $NV = \frac{ri}{2}$ and the same premises, NV would figure out as 10,000 board feet per acre.

Munger's formula is undoubtedly well adapted for selection forest.

80. Comparison of Actual with Normal Distribution of Age-Classes. — In even-aged forests the degree of approach toward normality may be judged by comparing the actual and the normal age-class distribution. This comparison may be done graphically as shown in Fig. 25. Of the two methods, the one by rectangular blocks is to be preferred, since it is clearer and can be kept posted by decades so as to reveal the progress of the management towards the goal of normality.

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* Proceedings Society of American Foresters, Vol. X, No. 1, pages 18–21. The example which Munger gives on page 20 is for 50 acres since $\frac{325{,}000}{50} = 6500$.

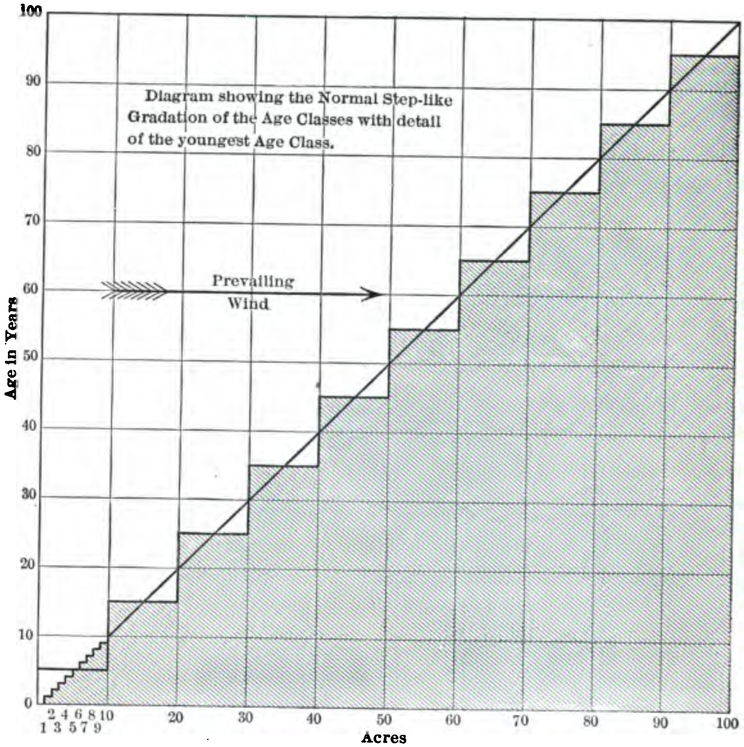
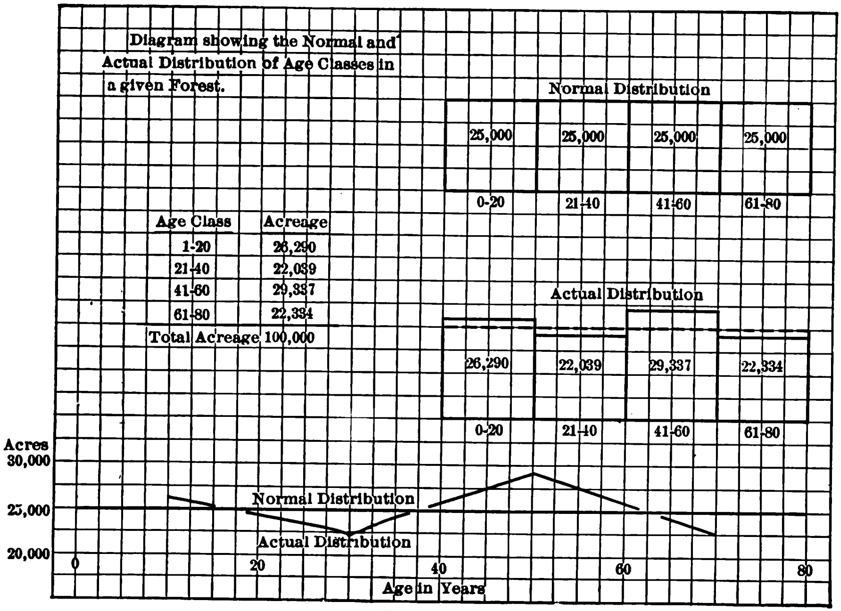


FIG. 24.



Age Class	Acreage
1-20	26,290
21-40	22,039
41-60	29,337
61-80	22,334
Total Acreage	100,000

FIG. 25.

81. Division of the Area. — In order to facilitate the management of a forest it is systematically divided into units of area. A forest may be divided from various points of view into units, either localized in the field or differentiated in the working plan, or both.

The usual subdivisions of a forest are:

(1) *Working unit:* (Syn.: working plan unit.) A forest area managed under one working plan. It may or may not coincide with the administrative unit.

(2) *Working group:* (Syn.: management class, working block; working circle, working section.) An organization or working plan unit, comprising an aggregate of compartments or stands to be managed under the same silvicultural method and rotation. (The terms *compartment, silvicultural method,* and *rotation* will be made clear in this chapter; *stand* is a general descriptive term referring to an aggregation of trees, standing on a limited area, of more or less uniformity of composition and condition, or of age.)

(3) *Block:* A major division of the working unit, intermediate in size between the working unit and a compartment. A block is usually based on topography and comprises a main logging unit or group of logging units. A single block may contain many thousand acres.

(4) *Compartment:* A unit of forest organization for purposes of orientation, administrative, and silvicultural operations. It may or may not coincide with the public land survey. There may be an indefinite number of compartments in a block. The limits of a compartment are rectilinear in the plains and follow topographic features in hill and mountain country. The area of a compartment varies with the intensity of management and seldom exceeds 500 acres. In a forest under complete management, the compartment boundaries are shown on the forest maps and are permanently marked on the ground by blazed lines, durable monuments, posting, roads, trails, streams, or other well-defined natural features.

(5) *Lot:* (Syn.: Sub-compartment.) A small sub-division of a compartment differing in composition, age, or character, requiring different treatment from the main body of the compartment; impermanent if due to accidental; permanent if due to site conditions.

82. Designation of Divisions. — Working units and blocks are given names and blocks are sometimes numbered as well; compartments are numbered; sub-compartments are lettered. *E.g.*, a paper-birch thicket in a spruce compartment on the lower slopes of Mount Tecumseh block in the Waterville, N. H., basin, would be designated as 29*a*, Tecumseh Block, Waterville Unit.

83. Boundaries of Divisions. — Before designating the boundaries of any working-plan divisions, either in the field or on the map, the forest organizer, in consultation with the owner and the administrator of the forest, or both, should decide just what divisions are to be made and on what basis. The determination of working units is a *sine qua non*, but whether blocks, compartments, and sub-compartments are also to be segregated depends entirely on the specific needs of the forest. Large forests should almost always be divided into blocks. The further sub-divisions into compartments and sub-compartments is necessary only where intensive working plans are practicable.

Having decided just how far to go in the matter of divisions, the forest organizer keeps this in mind during his preliminary reconnaissance and during the entire progress of the field work. The detail of forest description and the unit described depend on the extent of sub-division. That is, if blocks are the minimum divisions possible, the organizer needs only the briefest descriptions by sections or other survey units and a more detailed general description by watersheds or other appropriate logging units. If, on the other hand, the refinements of compartments and sub-compartments are possible, the unit of description must be the stand, and the forest description of each stand must be sufficiently detailed so that the forest organizer can determine therefrom whether to make it a sub-compartment, and its function in regulating the cut.

Obviously, therefore, the provisional boundaries of the minimum unit of division decided upon must be noted in the progress of the forest survey and noted on the map.

As the work of gathering the data progresses, the forest organizer keeps always in mind the possible division of the forest, and, map in hand, goes through the area to determine its most advantageous arrangement. His task will be the easier if the forest description data are well and carefully gathered.

On the map the boundary of the working unit is marked by heavy dot and dash — . — . — . —.; the blocks by dashes ---------; the compartments by a dotted line ....; and the sub-compartments by a thin, unbroken line ————.*

84. Working Plan Conference. — Before organizing a forest for management, a consultation, known as the working plan conference, should be had between the owner or administrator and the forester who is to make the working plan. This conference should decide, first of all, the wishes and purpose of the owner or administrator regarding the tract. Next it should determine, with reference to the forest survey, what data are requisite and what methods shall be used in securing these data, and in how much detail the work is to be done, including the division of the area into blocks, compartments, etc. The permissible cost of the field-work should also be decided.

It is well if the results of this conference are put in writing and the document signed by each of the participants.

After the fundamental wishes and purposes of the owner and the essentials of the field-work have been fixed, then further points must be decided. These are:

1. The objects of management to be attained.
2. The silvicultural methods to be used.
3. The rotations to be employed.

These will be considered in the order named.

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* References: Roth, "Forest Regulation," pages 34–43; Illick, "The Subdivision of Forests," For. Quart., Vol. XIII, 2, pages 183–198.

85. Objects of Management. — At the working-plan conference the objects for which the forest is to be managed must be decided, *i.e.*, whether:

(*a*) For sustained yield.
(*b*) For exploitation.
(*c*) For protection (watershed protection).
(*d*) For æsthetic purposes.
(*e*) For a game preserve, or how far each or all of these or any other consideration is to govern.

If the forest is to be a continuously productive one, the next point to decide is the class of product desired, such as: sawtimber, cordwood, mining timber, turpentine, etc.

86. Silvicultural Methods. — The conference should determine whether the forest is to be managed as:

(*a*) *High forest, i.e.*, a forest originating from seed.
(*b*) *Coppice forest, i.e.*, a forest consisting wholly or mainly of sprouts.
(*c*) *Coppice with standards, i.e.*, a forest in which both seedlings and sprouts are used in reproduction, the seedling growth forming the standards. This is known as *composite forest.*

If high forest is chosen, the method of reproduction must be determined provisionally. A method of reproduction is an orderly procedure or process by which a forest is renewed or established, either naturally (by self-sown seeds) or artificially (by direct seeding or planting). The following methods are distinguished:

1. Clearcutting, artificial reproduction.
2. Clearcutting, natural reproduction.
3. Seed tree method.
4. Selection method.
5. Shelterwood method.

These methods are defined and explained as follows:

1. *Clearcutting with Artificial Reproduction.* — Removal of the entire stand in one cut with artificial reproduction or reforestation by direct seeding or by planting.

G., Kahlschlagwirtschaft. F., Méthode par coupe unique.

2. *Clearcutting with Natural Reproduction.* — Removal of the entire stand in one cutting, reproduction taking place by seed from the marginal stand or seed in the ground. Differentiation may be made according to the form of cutting area into strip and group method. *Strip method:* (G., Saumhieb, F., Coupe par bandes.) Cutting a strip, and when regeneration has taken place by marginal seeding, *seaming* an additional strip and proceeding in this manner from year to year or period to period. A variant called *strip method in echelons* (G., Kulissenhieb, Springschlag. F., Coupe par bandes alternes) opens strips in several places at the same time and then proceeds similarly by seaming. The *group method* (G., Kesselhieb, Löcherhieb; F., Coupes par trouées) proceeds by removing groups of trees making more or less irregular openings and enlarging these until the entire stand is removed.

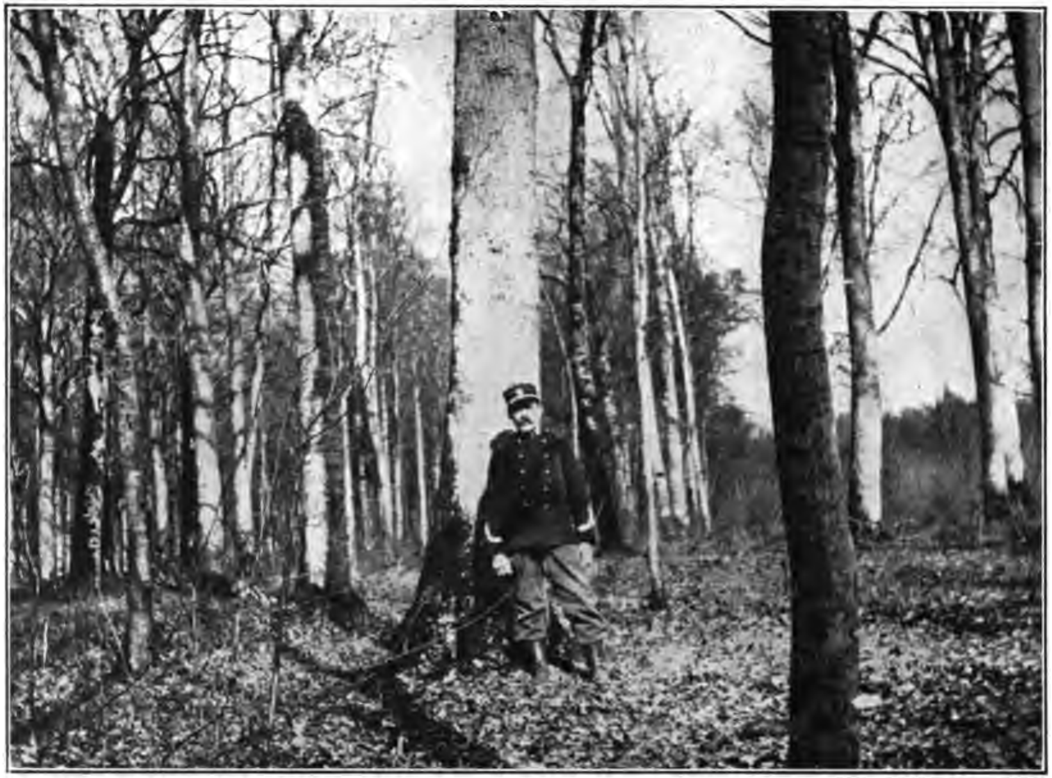
3. *Seed Tree Method.* — Removal of the entire stand at one cut, but leaving a *small number* of seed trees singly or in small groups, to be eventually removed If the seed trees are held over for another rotation, this may be called *reserve tree method.*

4. *Selection Method.* — That method of cutting in which single trees, usually the largest, or small groups of such trees, are removed and reproduction secured under the remaining stand and in the openings. When groups of trees are taken, it is termed *group selection method,* G., Plenterbetrieb, Femelbetrieb. F., jardinage, régime de la futaie jardinée.

A special form of the selection method is termed *selection border cutting* or *strip selection* when selection cuttings are made in narrow strips, in most instances beginning on the north border and progressing southward, followed by clearcutting when young growth is fairly established, with the expectation of additional marginal seeding. The resulting forest is unevenaged in narrow lines. G., Blendersaumschlag.

5. *Shelterwood Method.* — A method of securing natural reproduction under the temporary shelter of the seed tree crown cover, by means of a series of cuttings throughout the stand, aimed to admit a gradually increasing supply of light to the seedlings. The principle of the method lies in the protection

PLATE II.



Coppice with Standards. Forêt de la Hâye near Nancy, France. The forest officer is a District Ranger or "Brigadier."

(*shelter*) which the seed trees (*nurse trees*) afford the young growth during its youth. G., Schirmschlagbetrieb (Gayer & Lorey), in part Femelschlagbetrieb (Lorey). F., régime de la futaie regulière. The number and severity of the cuttings and hence the duration of the entire removal period, depends upon the rate of establishment and the need of light by the young growth. In theory the sequence of cuttings is divided into four parts as follows:

Preparatory cuttings fit the stand for its reproduction by the removal of dead, dying, or defective trees and undesirable species, and prepare the ground for the seed-bed and encourage seed production. A stand in which one or more preparatory cuttings have been made is in the preparatory stage. G., Vorbereitungschlag. F., coupe préparatoire.

Seed Cutting. — A further opening of the stand, before seeding takes place, to secure the amount of light which the expected seedlings will require. A stand in which one or more seed cuttings have been made is in the seeding stage. G., Besamungschlag. F., coupe d'ensemencement.

Removal cuttings gradually remove the mature stand, which would otherwise retard the development of the young trees. A stand in which one or more removal cuttings have been made is in the removal stage. G., Lichtschlag. F., coupe claire.

The *final cutting* is the last of the removal cuttings, in which all of the old stand still remaining is cut. (G., Abtriebsschlag, Endhieb. F., coupe définitive.) In practice a two-cut shelterwood method may be used, including the seed cutting and final cutting stages. The shelterwood method may be applied to a stand in narrow strips, from the leeward side, at such intervals that reproduction cuttings are generally going on in three strips at one time, one strip being in the removal stage, one in the seeding stage, and one in the preparatory stage. This manner of application is termed *shelterwood strip method.*

Another modification of the shelterwood method of reproduction is that in which groups of valuable advance growth, if present, form the starting points for the cutting which radiates from these centers. Such an application is termed ***shelterwood group method.***

The specific application of these various methods to given conditions is the province of silviculture and is fully described in books on that subject. The choice of methods must always depend upon conditions on the ground. A brief discussion of the applicability of the chief methods may, however, prove helpful in reaching such a decision. The accompanying chart shows the possible methods of reproducing the most important species.

87. The Clearcutting Methods.* — All methods of natural reproduction from seed trees not standing on the area to be reproduced are much more uncertain than either the selection or shelterwood methods. When the area is clearcut or denuded by fire or other causes, soil deterioration is likely to occur and the ground to become covered with a more or less dense growth of herbage, making reproduction more and more difficult the longer it is delayed. Clearcutting methods, because of the difficulties and uncertainties in attaining natural reproduction, usually result in artificial reproduction being required at least to supplement the natural seeding and the new stand is established at once. Artificial reproduction is often advantageous because it is more certain of success. Furthermore only the species desired are reproduced.

The strip method of clearcutting depends for effectiveness upon the width of the strips, *i.e.*, the narrower the strips the more abundant and uniform the distribution of the seed, and, under favorable soil conditions, the better the reproduction. The success of this method depends also upon the points of attack, *i.e.*, the direction of the strips in reference to the prevailing wind and the shade cast by the remaining stand.

The group method of clearcutting requires small openings. The smaller the openings are, the better and more uniform the reproduction and the closer the approach to the selection or

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* The following four articles are adapted from "Seeding and Planting in the Practice of Forestry," by J. W. Toumey, John Wiley & Sons, Inc., New York, 1916.

✕		✕				
✕	Combined ↔	2 cuts ✕				Also occurs in Pacific Coast Forest. Same methods.
✕						Also occurs in Pacific Coast Forest. Same methods.
✕						"Douglas fir in the Rocky Mts. may never be cut clear, even though this were but from the silvicultural standpoint" Bates, Proc. Soc. Am. For., VII, 1, p. 109.
						"Cut clear (to lowest merchantable diameter limit) and burn over the surface... should be the general plan.... except on steep slopes with shallow soil" U. S. F. S. Circ. 150, p. 32.
✳						Also occurs in Pacific Coast Forest. Same methods.
		✕ Feasible				Also occurs in Rocky Mountain Forest. Same methods.
✕		✕				
✕				✕		

njunction with the associated species, as well as in pure stands. The chart is based on pub-
acteristics of the species. The applicability of any one method is based primarily on consid-

shelterwood methods. In the practice of this method, advantage is usually taken of openings already existing in the stand due to windfall or other causes, and their area is gradually increased with the progress of reproduction. This method applies best to uneven-aged stands of wind-resistant species.

88. The Seed Tree Method. — This method can seldom be depended upon to attain satisfactory reproduction. Except with the most wind-resistant species, the seed trees left are liable to be blown over. The species must produce seed having great carrying power, the soil must be receptive, and the reproduction must be attained quickly or the growth of herbage will prevent. The seed tree methods have proved most useful abroad when used in connection with artificial reproduction. The scattered seed trees are of other species which through natural reproduction introduce age variety, as well as variety in species, into the otherwise even-aged artificial stand.

89. The Selection Method. — Natural reproduction is most easily attained in forests managed by the selection method, although in such forests it is often difficult to regulate the composition. The selection method is applicable to stands represented by trees of all ages. In such stands, trees are taken out here and there as they mature while the younger trees remain standing. Only a small percentage of the entire stand is cut at one time. The openings made by the removal of single trees or small groups of trees are always small. Because of the abundance of nearby seed trees and the protection afforded the soil, the openings are quickly filled with young trees in vigorous growth. Reproduction in a selection forest most nearly approaches that of a virgin forest, the chief difference being that in the selection forest the small openings are made by the removal of mature trees, while in the virgin forest the openings are made through the death and decay of the overmature trees.

90. The Shelterwood Method. — The shelterwood method is applicable to relatively even-aged stands. The mature crop is removed gradually by a series of cuttings. From 10 to 15 years usually intervene between the first cutting and the removal of the last of the crop. During this interval reproduction takes place. From the standpoint of reproduction, this method has many advantages. The cuttings leave a large number of seed trees more or less uniformly distributed. The shelter of the trees left protects the soil and the young seedlings and retards the growth of weeds, grass, and brush. The seed is provided in abundance and is well distributed. As the new growth is established before the last of the old trees is removed, the soil is not exposed as is the case in clearcutting.

91. Rotation. — By rotation is meant the predetermined time period during which it is intended to cut over a working group; the predetermined, *approximate* felling age of stands. Rotation refers to the forest as a whole and is expressed not by a definite year, but a period of ten to twenty years; *felling age* refers to a stand and a definite year.

Rotations are determined by (1) technical, (2) economic, and (3) financial considerations, silvicultural considerations exercising a limiting influence. They are designated accordingly.

92. Technical Rotations. — These attempt to produce the maximum amount of material suitable for a certain purpose, such as railroad ties, mine timbers, saw logs of given size and the like.

For example, railroad ties cannot be made from trees less than ten inches in diameter at breast-high. If, therefore, an owner in southern Connecticut desired to grow chestnut sprouts for this purpose it would require 50 * years for the average tree to reach 10 inches d.b.h., on the best sites. At this age † there would be 435 standard ties produced per acre besides 35 cords of cordwood.

Another example may be taken from the Pacific Coast. To produce suitable saw-timber from Douglas fir, the trees should be at least 16 inches d.b.h. If, therefore, an owner in western Washington desired to grow Douglas fir for this purpose it would require ‡ 70 years for the average tree to reach 16 inches d.b.h. on the best sites. At this age § there would be 56,500 feet, board measure, produced per acre. For further examples, see pages 238 to 242 in the Appendix.

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* According to Table 17 of Bul. 96, Forest Service, U. S. Dept. of Agriculture, "Second Growth Hardwoods in Connecticut."

† Table 28, *ibid.*

‡ Table 1, For. Quart., Vol. XII, page 442.

§ *Ibid.*

This rotation is the one most commonly used in the United States. It is easily applied, and, if conservatively chosen, will give satisfactory results. In this, as in all rotations, the silvicultural considerations exercise a limiting influence. For example, where reproduction is by natural methods, such as the shelterwood method, some of the trees will have to be left beyond the rotation age in order that the seed from them may re-stock the area cut. This space of time required for the renewal of a stand constitutes the *reproduction period* and must be added to the rotation age.

93. Economic Rotations. — These attempt to secure either the maximum average volume production, or the maximum average value production.

The higher the average yearly production of a piece of woodland, the greater, of course, will be its continuous producing value if cut over repeatedly. For example, in the second-growth hardwoods in Connecticut [*] the average annual growth in cubic feet and cords culminates as follows:

Chestnut type: best sites and medium sites............	35 years
Chestnut type: poorest sites.........................	40 years
Oak-chestnut type: best sites and medium sites.........	30 years
Oak-chestnut type: poorest sites......................	35 years
Oak type: best sites and medium sites................	35 years
Oak type: poorest sites.............................	40 years

These lengths of rotation are so nearly similar that it is safe to place the cordwood rotation for second-growth hardwood stands at from 30 to 40 years. To illustrate how silviculture enters in as a limiting factor, the rotation for stands containing much red, black, or scarlet oak should be 30 or even 25 years in order to secure successful sprout reproduction of these species.

Another example of the economic rotation may be taken from Douglas fir on the Pacific Coast. According to published tables [†] the economic rotation for cubic volumes and board-foot volumes for best, medium, and poor sites, in western Washington and Oregon is as follows:

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[*] Bul. 96, Forest Service, U. S. Dept. of Agri., Tables 30, 32, and 33.

[†] For. Quart., Vol. XII, page 447, table 6.

Site quality.	Cubic volume.		Board-foot volume.	
	Rotation, years.	Yield per acre, cu. ft.	Rotation, years.	Yield per acre, bd. ft.
Best	52	9050	110	100,000
Medium	55	8110	110	74,000
Poor	52	5650	115	58,000

A rotation of from 50 to 55 years could safely be chosen for maximum production in cubic contents and of 110 to 115 years for maximum production in board-foot contents.

Unlike the technical rotation, this rotation finds but little application today, since it usually takes quantity of material as the goal. It is satisfactory from the silvicultural standpoint, hence it is sometimes spoken of as a "silvicultural rotation."

94. Financial Rotations. — These introduce considerations of cost and attempt to secure either the maximum *forest rent* or maximum *soil rent*.

Forest rent is the net income from a forest organized for sustained yield, without interest charges on the forest capital — the forest, *i.e.*, soil with a stand or growing stock, being conceived as the forest capital, and the rent as the total interest earned by it.

In other words, it is "a mere bookkeeper's balance of income and outgo, under annual management, without consideration of time of income or outgo, forest and soil representing the capital producing the rent as an annual receipt, like a house and lot producing the annual rent." *

The Norway spruce will serve as an example of financial rotation based on forest rent. According to European tables (Endres, after Schwappach) the gross income, expenses, and net income per acre for different decades is as follows for medium sites.†

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* From letter by Dr. B. E. Fernow, to one of the authors, under date of February 23, 1914.

† Taken from "Forest Valuation," Roth, Ann Arbor, Mich., 1916.

Years.	Gross income per acre.	Expenses per acre.			Net income per acre.	
		Initial (planting).	Current ($0.90 per year.)	Total expense.	Total.	Average.
	$	$	$	$	$	$
30	87	12	27	39	48	1.60
40	210	12	36	48	163	4.00
50	402	12	45	57	354	6.90
60	654	12	54	66	588	9.80
70	923	12	63	75	848	12.10
80	1212	12	72	84	1129	14.10
90	1474	12	81	93	1382	15.30
100	1710	12	90	102	1609	16.00
110	1919	12	99	111	1808	16.40
120	2087	12	108	120	1967	16.30

From this table it is evident that the highest net income occurs at 110 years and this, accordingly, would be the financial rotation chosen on the basis of *forest rent.*

Soil rent is that part of the income (or balance) from a managed forest which remains as interest on the soil capital alone after all expenses with compound interest have been deducted, the soil alone being conceived as the capital.

In other words it "considers the soil alone as capital, the forest stand representing the accumulated interest on that capital. It is, therefore, based on intermittent returns and hence requires a compound interest calculation; it is a financier's balance as compared with a bookkeeper's balance." *

A good example of financial rotation based on soil rent is found in European tables. The following figures are taken from Endres' "Valuation" and Schwappach's "Tables of Growth." Assuming an interest rate of 3 per cent compounded, the income value per acre for different decades and different species is as follows: †

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* Letter from Dr. Fernow.

† Taken from "Forest Valuation," Roth, Ann Arbor, Michigan, 1916.

Years.	Norway spruce.			White fir.		Scotch pine.		Beech.	
	Best sites.	Medium sites.	Poor sites.	Best sites.	Poor sites.	Best sites.	Poor sites.	Best sites.	Poor sites.
	Dollars per acre.								
30	51	10	−14	−10	−30	43	−3	4	−19
40	100	47	13	67	− 5	59	7	25	− 4
50	139	77	38	134	25	66	13	32	6
60	159	98	53	156	38	67	13	35	7
70	166	105	59	156	44	64	13	35	7
80	161	105	59	145	44	59	10	34	4
90	151	99	56	130	41	53	8	31	2
100	138	91	51	114	36	48	5	27	2
110	126	83	46	99	30	43	4	24	− 2
120	117	75	41	86	25	40	2	21	− 4

From this table it is evident that for Norway spruce, medium sites, the financial rotation chosen on the basis of *soil rent* would be 70 or 80 years; for white fir 70 years; for Scotch pine 60 years; and for beech 60 or 70 years.

The financial rotation will undoubtedly be used more and more in the future especially as the necessary data become available. "In any ordinary forest business the aim is to keep the forest and land in best possible condition and at the same time make the largest income. Assuming the silvicultural conditions cared for, the best rotation is the one furnishing the best income for the longest time. There are two distinct ways of judging this income.

"(1) . . . the largest net income per acre of established forest." (Forest Rent.)

"(2) . . . the largest per cent on the money invested in the forest." (Soil Rent.)*

95. Choice of Rotation. — The kind of rotation to adopt depends on matters of policy, to wit:

1. Conditions of ownership, wishes, and purpose of owner.
2. The market and logging conditions.
3. The site.
4. The character of the stand.

* "Forest Valuation," Roth, page 85.

1. The state can afford a higher rotation than can the private owner; furthermore, it is the duty of the state to grow timber not only for profit, but to supply future demand, especially in sizes requiring long rotations.

2. The market conditions influence the rotation, inasmuch as good markets and easy accessibility permit shorter rotations, whereas forests further from market and more difficult of access necessitate a longer rotation to make logging at all profitable. The decreasing area of virgin forests and the rapidly increasing population justify the consideration of future as well as present market conditions. It is reasonable to expect that the price of larger timbér will increase proportionately more than that of smaller sizes, and hence it may be good economy, in view of future market prices, to adopt a longer rotation and plan to grow larger sizes of timber than present market prices would warrant.

3. The more the site is adapted to a certain species, the longer can the rotation be. Conversely the more rapid growth on good sites will often tend to shorten the rotation.

4. The character of the stands influences the rotation in respect to their quality and species. The better the quality of the stand, the longer can the rotation be; the less thrifty stands will often have to be cut before the regular rotation age. The species in mixed stands can usually be worked on the same rotation unless they mature at different ages or are markedly different in value, *e.g.*, a mixed forest of Engelmann spruce and white fir (A. concolor) will often require a higher rotation for the spruce than for the fir; because the fir deteriorates at an earlier age and becomes almost valueless at a time when the spruce is just fully matured.

In conclusion, as Roth says,* "rotation should be chosen no longer than is necessary to produce desired material, a good income from the land, with full assurance that the fertility of the land is not impaired."

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* "Forest Regulation," Roth, Ann Arbor, Michigan, 1914, page 117.

CHAPTER XIII

REGULATION OF THE CUT

96. Definition. — By regulation of the cut, or, as it is sometimes called, regulation of felling budget, or regulation of yield, is understood the fixation in advance of the annual or periodic cut, which in the normal forest would be equivalent to the annual growth. The regulation of cut is necessarily preceded by a *determination* of the amount to be cut and by the *location* of the areas to be cut over. The regulation of cut finds its expression in the general and annual *cutting plans*. (See Article 106.)

97. Determination of Cut. — Of the many* methods for determining the allowable annual cut — *i.e.*, the cut which will not be in excess of the sustained yield, only the simplest and most useful ones need be given here. In general, these methods are based either (1) on area, or (2) on volume, or (3) on area and volume.

The most important single factor in deciding on a method of determining the cut is the silvicultural method chosen, especially as to whether it results in an even-aged forest or in an uneven-aged (selection) forest. The clearcutting, the seed tree, the shelterwood, and the coppice methods all result in an even-aged forest. The selection method results in an uneven-aged forest. Methods applicable to each form of forest will be given according as the basis is area, or volume, or both.

98. Determination of Cut in Even-aged Forests. By Area — (*a*) *Description of Method.* — The forest is divided into a number of cutting areas (annual or periodic) corresponding to the rotation age. These annual or periodic cutting areas are marked on the ground; annually or periodically, a cutting area is logged. The size of the cutting areas is either exactly the same or else is equal to the reduced area corresponding to the varying site qualities.

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* Eighteen distinct methods are described in "Forest Working Plans," Recknagel, John Wiley & Sons, Inc., N. Y., 2nd Edition, 1917, pages 67–124.

(*b*) *Example.* — A forest of white pine contains 1800 acres. It is to be managed on a rotation of 60 years. The annual cutting area $= \frac{A}{r} = \frac{1800}{60} = 30$ acres. If the cutting period is 20 years, then the periodic cutting area will be $30 \times 20 = 600$ acres.

By reduced area the results would be as follows: Each site quality produces for a fully-stocked stand a varying volume at the rotation age. For white pine it has been determined * that the maximum yield (Site I) for a 60-year rotation is 60,200 board feet per acre, the minimum (Site III) 33,600 board feet per acre, the average (Site II) 46,900 board feet per acre.

As compared with Site I, Site II yields 78 per cent and Site III, 56 per cent. These are the factors of reduction to the common site quality (I).

If, in the above instance, the actual area of 1800 acres was composed equally of each site quality, then the reduced area would be:

Site I, original 600 acres, reduced 600 acres.
Site II, original 600 acres, reduced 468 acres.
Site III, original 600 acres, reduced 336 acres.
Total, original 1800 acres, reduced 1404 acres.

The annual or the periodic cutting area is, therefore, varied according to the site quality or qualities in the area allotted. For example, the annual cutting area $= \frac{\text{reduced area}}{\text{rotation}} = \frac{1404}{60} =$ 23.4 acres. Similarly, the periodic cutting area $= 23.4 \times 20 =$ 468 acres.

If the annual cut of 23.4 acres was all to be taken from Site III stands, it would actually require: $23.4 \times 1.79 = 41.9$ acres; for, from the above percentages, it requires: 1.28 acres of Site II to equal 1 acre of Site I, and 1.79 acres of Site III to equal 1 acre of Site I.

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* Table 6, Bul. 13, U. S. Dept. of Agric., "White Pine under Forest Management."

(*c*) *Value and Application.* — This is the oldest and simplest method of determining the cut. It is useful in coppice forests and as an "area check" on results secured by other methods.

99. Determination of Cut in Selection Forests. By Area — (*a*) *Description of Method.* — In the management of the selection forest the cutting cycle — *i.e.*, the planned interval between fellings or cuts on the same forest area — is of more real importance than the rotation. The cutting cycle, in turn, depends on the time required for reproduction and on the growth so that it may pay to log the same area again. The allowed annual cutting area is not $\frac{A}{r}$, therefore, but $\frac{A}{cc} = \frac{\text{area}}{\text{cutting cycle}}$, and the volume to be cut is found by multiplying $\frac{A}{cc}$ by the amount to be removed per acre.

(*b*) *Example.* — A tract of 1730 acres of hardwoods forest in the Catskill Mountains is to be managed under the selection method. Careful studies indicate a cutting cycle of 40 years; of the 5090 board feet per acre present on the tract today, 3400 board feet per acre are to be removed in the selection cutting. The allowed annual cut for the first cutting cycle therefore is:

$$\frac{A}{cc} \times \text{volume to be removed per acre.}$$

$$\frac{1730}{40} \times 3400 \text{ board feet} = 147{,}050 \text{ board feet.}$$

(*c*) *Value and Application.* — As in the even-aged forest, the determination of the cut by area is chiefly to be used as a check on determinations of the cut by other methods.

100. Determination of Cut in Both Even-aged and Selection Forests. By Volume. — Two methods will be given: *Von Mantel's* and *Heyer's*.

I. *Von Mantel's Method.* (*a*) *Description of Method.* — Von Mantel bases his method on the conception of a normal forest in which, as explained in the previous chapter (Article 79), the growing stock $= \frac{r \times i}{2}$, that is, the mean annual increment multiplied by half of the rotation.

Since, as was shown in Fig. 22, the volume present in any forest in any one year (NV in normal forest) equals one-half of the total volume produced during the entire rotation ($r \times i$); therefore the annual cut = volume present ÷ by half the number of years in the rotation. In normal forest $NV = \frac{r \times i}{2}$ and i (the annual cut) $= \frac{NV}{\frac{r}{2}}$, or, as Von Mantel writes it:

$$\text{Annual cut} = \frac{V}{\frac{r}{2}}.$$

(*b*) *Example.* — A forest of 100 acres of white pine near Ithaca, N. Y., is to be managed on a rotation of 80 years. The area and volume of the age-classes are as follows (see Article 79 and Fig. 23):

I (1–20 years)	20 acres	negligible volume
II (21–40 years)	30 acres	258,000 board feet
III (41–60 years)	23 acres	408,250 board feet
IV (61–80 years)	27 acres	642,060 board feet
	100 acres	1,308,310 board feet

$$\text{The annual cut} = \frac{V}{\frac{r}{2}} = \frac{1,308,310}{\frac{80}{2}} = \frac{1,308,310}{40} = 32,708 \text{ board feet}$$

An example of the application of this method in selection forests can be given by using the data in Article 99. The rotation is taken as 160 years.

$$\text{Annual cut} = \frac{V}{\frac{r}{2}} = \frac{5090 \times 1730 \text{ acres}}{\frac{160}{2}} = \frac{8,805,700}{80}$$
$$= 110,071 \text{ board feet}$$

(*c*) *Value and Application.* — This has been termed the method of "glorious simplicity," because it requires no other data than the volume of the growing stock and the rotation. However, it is based on the premise of a normal forest and the correctness of its results varies with the degree of approach to normal. Since most of our forests are far from normal the results may be misleading. Its use is, therefore, restricted to determining the cut provisionally before detailed data can be obtained and as a check on the results obtained by other methods.

II. *Heyer's Method.* (*a*) *Description of Method.* — Heyer writes his formula:

$$\text{Annual cut} = \frac{V + ix - NV}{x},$$

in which V is the actual growing stock, i is the actual mean annual increment, NV is the normal growing stock and x is the period of years over which the surplus of V over NV (or the deficit if $NV > V$) is to be distributed. A simpler way to write the formula is: annual cut $= i + \frac{V - NV}{x}$. The period x can be determined only with regard to local exigencies (markets, etc.); it must be developed out of a general plan of management which is in consonance with the wishes of the owner.

(*b*) *Example.* — Taking the data given above for the example of Von Mantel's Method in even-aged forests, the mean annual increment can be determined by taking the volumes given for each age-class and dividing by the average age, thus:

Age-class I, M.A.I. = negligible vol.

$$\text{Age-class II, M.A.I.} = \frac{258{,}000}{30} = 8600 \text{ board feet.}$$

$$\text{Age-class III, M.A.I.} = \frac{408{,}250}{50} = 8165 \text{ board feet.}$$

$$\text{Age-class IV, M.A.I.} = \frac{642{,}060}{70} = 9172 \text{ board feet.}$$

$$\text{M.A.I. Total} = 25{,}937 \text{ board feet.}$$

$$NV = \frac{ri}{2} = \frac{80 \times 25{,}937}{2} = 1{,}037{,}480 \text{ board feet.}^*$$

$$V = 1{,}308{,}310 \text{ board feet.}$$

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* If the normal M.A.I. for 80 years is used as read from the yield table given in Fig. 23, $NV = \frac{ri}{2} = \frac{80 \times 330}{2} = 13{,}200$ board feet per acre, or for 100 acres = 1,320,000 board feet. However, the actual rather than the normal M.A.I. is commonly used.

Let $x = 20$ years (the first working period).

$$\text{Annual cut} = i + \frac{V - NV}{x} = 25{,}937 + \frac{1{,}308{,}310 - 1{,}037{,}480}{20}$$

$$= 25{,}937 + \frac{270{,}830}{20} = 25{,}937 + 13{,}542 = 39{,}479 \text{ board feet.}$$

An example of this method in selection forests can be given by using the data given in Articles 99 and 100 for 1730 acres of hardwoods forest in the Catskill Mountains. The increment (current annual, which may be used in place of M.A.I. in the selection forest) is as follows, for 1730 acres.*

Hemlock	8,055 board feet
Beech	15,996 board feet
Birch	42,913 board feet
Maple	25,506 board feet
Miscellaneous	21,484 board feet
Total i =	113,954 board feet

r, the rotation = 160 years.

$$NV, \text{ the normal growing stock} = \frac{ri}{2} = \frac{160 \times 113{,}954}{2}$$

$$= 9{,}116{,}320 \text{ board feet.}$$

V, the actual growing stock = 8,805,700 board feet. (A deficit).

x, the period of distribution = 40 years (the first cutting cycle).

$$\text{Then the annual cut} = i - \frac{NV - V}{x}$$

$$= 113{,}954 - \frac{9{,}116{,}320 - 8{,}805{,}700}{40}$$

$$= 113{,}954 - \frac{310{,}620}{40}$$

$$= 113{,}954 - 7766 = 106{,}188 \text{ board feet.}$$

(*c*) *Value and Application.* — Heyer's Method is directly applicable to the majority of American forests, especially to those where, as in virgin forests, the actual growing stock is far in excess of the normal growing stock and a reduction to normal is of prime importance. It is a very desirable method to use and furnishes a good comparison with the allowable cut as determined by other means.

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* See "A Practical Application of Pressler's Formula," For. Quart., Vol. XIV, No. 2, pages 260–267.

101. Determination of Cut in Selection Forests, by Volume. — Two methods will be given: The *Swiss* and *Hufnagl's*.

I. *Swiss Method.* (*a*) *Description of Method.* — The Swiss Method is described in an anonymous article on selection forest management in the Swiss Forestry Periodical for 1913, briefed in "Forestry Quarterly," Vol. XIII, No. 2, pages 260–262, as follows:*

"Divide the volume of the oldest size classes by the annual increment of the entire stand. This will give the number of years during which the volume of the oldest size classes must last. If this be forty-five (45) years, then the cut for the next decade would be from one-fifth to one-quarter of the volume of the largest size classes."

Expressed mathematically:

Let X = the volume of the size classes below the diameter limit.

Xi = the current annual increment thereon.

Y = the volume of the size classes above the diameter limit but within a satisfactory current annual increment of, at least, 1 per cent.

Yi = the current annual increment thereon.

Z = the volume of the size classes beyond a satisfactory current annual increment of, at least, 1 per cent — that is overmature timber — surplus growing stock.

Zi = the current annual increment thereon.

CC = the cutting cycle.

Then $$CC = \frac{Y + Z}{Xi + Yi + Zi}.$$

And annual cut $$= \frac{Y + Z}{CC}.$$

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* See also "A Practical Application of Pressler's Formula," For. Quart., Vol. XIV, No. 2, pages 260–267, especially pages 264–267.

This is the strict interpretation of the method as described, but since Z is surplus growing stock it should play no part in determining CC. Nor should the increment thereon (Zi).

Then $$CC = \frac{Y}{Xi + Yi}.$$

And annual cut $$= \frac{Y + Z}{CC}.$$

(*b*) *Example.* — Using the data given in Article 100 for the 1730 acres of hardwoods forest in the Catskills, it appears that the current annual increment for the hemlock, for example, is made up as follows:

D.B.H., inches.	C.A.I. per cent. (Pressler.)	Volume on average acre. (Stock table.)		C.A.I. per acre.	
	Per Cent	Board Feet.		Board Feet.	
7	7.19	6.80	X	0.488	Xi
8	4.30	6.41		0.276	
9	4.00	12.18		0.487	
10	2.69	17.98		0.484	
11	2.68	24.09		0.645	
12	2.26	28.83		0.652	
Diameter limit.					
13	2.08	26.68	Y	0.555	Yi
14	1.75	21.45		0.376	
15	1.55	15.48		0.240	
16	1.69	18.36		0.310	
17	1.48	22.23		0.329	
18	1.24	20.51		0.254	
19	1.10	13.60		0.150	
Maturity limit.					
20	0.97	7.78	Z	0.076	Zi
21	0.89	17.56		0.156	
		continued in stock table (Table 5, Bul. 11, N. Y. Conservation Commission.)		5.478	

The same thing should usually be done for each species, and, of course, separately for each type.

Using the data given above and a 12-inch d.b.h. limit, the cut for hemlock figured by this method would be as follows:

$$\begin{aligned}
Y &= 138.31 \text{ board feet per acre.}\\
Z &= \underline{168.48} \text{ board feet per acre.}\\
Y + Z &= 306.79 \text{ board feet per acre.}\\
Xi &= 3.032 \text{ board feet per acre.}\\
Yi &= 2.214 \text{ board feet per acre.}\\
Zi &= \underline{0.232} \text{ board feet per acre.}\\
Xi + Yi + Zi &= 5.478 \text{ board feet per acre.}
\end{aligned}$$

Substituting, $CC = \frac{Y + Z}{Xi + Yi + Zi} = \frac{306.79}{5.478} = 56$ years and the annual cut $= \frac{Y + Z}{CC} = \frac{306.79}{56} = 5.478$ board feet, or, for the 1730 acres in the slope type = 9477 board feet of hemlock.

Eliminating Z and Zi in figuring CC:

$$CC = \frac{Y}{Xi + Yi} = \frac{138.31}{3.032 + 2.214} = \frac{138.31}{5.246} = 26 \text{ years.}$$

$$\text{Annual cut} = \frac{Y + Z}{CC} = \frac{306.79}{26} = 11.797 \text{ board feet,}$$

or, for the 1730 acres on the slope type = 20,409 board feet of hemlock.

For the other species in the Catskills, the cut, to a diameter limit of 16″ b.h. figures out as follows including Z and Zi:

Beech..........	10.878 board feet per acre;	18,819 board feet for 1730 acres
Birch..........	29.183 board feet per acre;	50,487 board feet for 1730 acres
Maple..........	17.345 board feet per acre;	30,007 board feet for 1730 acres
Others..........	14.610 board feet per acre;	25,275 board feet for 1730 acres

These volumes must, however, be reduced 15 per cent for local defect in the timber. The reduced values are:

Hemlock......................	8,055 board feet
Beech........................	15,996 board feet
Birch........................	42,913 board feet
Maple........................	25,506 board feet
Miscellaneous................	21,484 board feet
Total....................	113,954 board feet

(*c*) *Value and Application.* — This method is well adapted to finding the allowed annual cut in a selection forest. It should be used, however, in conjunction with some other methods, such as that next to be described (Hufnagl's) or Von Mantel's or Heyer's, and with an area check.

II. *Hufnagl's Method.* (*a*) *Description of Method.* — The prerequisites of this method are (1) a *stand table*, that is, a tabular enumeration showing separately for each diameter-class and species, the number of trees on a given unit of area, usually an average acre. (2) A *volume table*, that is, a tabular statement showing, for a given species, the average contents of trees of different sizes. (3) A *diameter growth table*, that is, a tabular statement showing the age of the average tree at various diameters. Such tables commonly result from a complete forest survey. The data for stand tables must be gathered locally but published data may be adapted for volume and growth tables.

Next it must be determined at what diameter and upward the trees are most merchantable. It follows that all trees of this diameter and larger are merchantable and should, other things being equal, be cut in the near future, *i.e.*, during the time required for the next lowest diameter-class or classes to produce an equal number of merchantable stems.

To express this numerically, let N equal the number of trees in any diameter-class as found in stand table (usually put in groups of 3 inches, to make calculations simple), let V equal the volume of the average tree of any diameter-class (found in volume table), and let A equal the age of the average tree of any diameter-class (found in growth table).

Let N_1, V_1 and A_1 represent the values for the diameter-class *just below* the chosen diameter limit of cutting. Let N_2, V_2, and A_2 represent the values of the next higher class and so on up to the maximum diameter limit, that is, the maximum diameter of trees which it is practicable to produce.* This usually leaves a surplus of still larger trees produced under virgin conditions. This surplus may well be distributed over the cutting cycle (*i.e.*, the time required for the maturity limit class to be replaced by the one next below it) or disposed of more rapidly or more slowly as seems best in view of local conditions.

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* F. H. Millen has aptly named this the "Maturity Limit."

Expressed as a formula:

$$\text{the allowed annual cut} = \frac{N_4}{A_4 - A_3}V_4 + \frac{N_3 - N_4}{A_4 - A_3}V_3 + \frac{N_2 - N_3}{A_3 - A_2}V_2 + \frac{N_1 - N_2}{A_2 - A_1}V_1.$$

(*b*) *Example.* — The stand table for the hardwood forest in the Catskills* shows considerable hemlock present. Hemlock becomes merchantable at about 12″ d.b.h. and, considering 3-inch classes, the minimum diameter may be taken to include trees 11″–13″ d.b.h., the maximum diameter which it is practicable to produce is taken as 18″ d.b.h. class (17″–19″), since trees 20″ and over have too slow a growth. (The c.a.i. = 1.10 per cent at 19″; 0.97 per cent at 20″ d.b.h.)

The 3-inch classes, the number of trees in each, the volume of the average tree, and the years required to grow from one class to the next are as follows:

D.B.H. class inches.	Volume per tree, board feet. (Table 9, Bul. 11.)	Number of trees per average acre. (Table 4, Bull. 11.)	Years required to grow from one class to the next.†
9	42 (V_1)	0.91 (N_1)	27 ($A_2 - A_1$)
12	93 (V_2)	0.87 (N_2)	32 ($A_3 - A_2$)
15	172 (V_3)	0.33 (N_3)	35 ($A_4 - A_3$)
18	293 (V_4)	0.20 (N_4)	....

† Based on increment borings, see "A Practical Application of Pressler's Formula," For Quart., Vol. XIV, No. 2, table 1, page 261.

Applying the formula, the annual cut =

$$\frac{N_4}{A_4 - A_3}V_4 = \frac{0.20}{35} \times 293 = 1.674 \text{ board feet per acre} +$$

$$\frac{N_3 - N_4}{A_4 - A_3}V_3 = \frac{0.13}{35} \times 172 = 0.637 \text{ board feet per acre} +$$

$$\frac{N_2 - N_3}{A_3 - A_2}V_2 = \frac{0.54}{32} \times 93 = 1.569 \text{ board feet per acre} +$$

$$\frac{N_1 - N_2}{A_2 - A_1}V_1 = \frac{0.04}{27} \times 42 = 0.062 \text{ board feet per acre.}$$

Total 3.942 board feet per acre.

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* See Table 4, Bul. 11, "Forest Survey of a Parcel of State Land," Conservation Commission, Albany, N. Y., 1915.

The tables show that trees 20″ and over have a volume of 168.48 board feet per average acre. This is surplus stock and may be disposed of in the next cutting cycle. Taking the cutting cycle as $= A_4 - A_3 = 35$ years and cutting 1/35 of this surplus each year = 4.814 board feet per acre, to be added to the 3.942 board feet already determined, making a total of 8.756 board feet per acre, or, for 1730 acres, 15,148 board feet of hemlock.

The cut for the other species, figured in the same way but with a 16″ diameter limit, is as follows:

Board Feet.		Reduced for Defect Board Feet.
Beech	= 29,756	25,293
Birch	= 62,242	52,906
Maple	= 77,591	65,952
Miscellaneous*	= 8,926	7,587
Hemlock	= 15,148	12,876
Total		164,614

* Using an average cutting cycle of 35 years for removing all over 16″ d.b.h

(*c*) *Value and Application.* — This method is perhaps the most practical yet devised for use in irregular selection forests.

102. Determination of Cut in Even-aged Forests. By Area and Volume. — (*a*) *Description of Method.* — For even-aged forests Hufnagl has shown that the allowed cut can be determined directly if the volume and the increment of the stands which now are more than half the rotation age are known. This method requires a tabulation of the volumes and areas of all stands over $\frac{r}{2}$ years old. To this volume is to be added the increment of the $\frac{r}{2}$ years old stands in the next $\frac{r}{4}$ years; for, since the area of these stands diminishes each year, the increment can only apply, on an average, to half the area.

Expressed as a formula, the annual cut $= \dfrac{V + \left(a \times i \times \frac{r}{4}\right)}{\frac{r}{2}}$.

(*b*) *Example.* — Using the data in Article 100, the rotation, $r = 80$ years, $\frac{r}{2} = 40$ years, $\frac{r}{4} = 20$ years. The area of the stands $\frac{r}{2}$ years and over = 50 acres, their volume = 1,050,310 board feet. From the example of Heyer's method, the mean annual increment of the stands of the III age-class ($a \times i$) is 8165 board feet; of the IV age-class it is 9172 board feet; a total increment of 17,337 board feet. Then, by formula,

$$\text{the cut} = \frac{V + \left(a \times i \times \frac{r}{4}\right)}{\frac{r}{2}} = \frac{1{,}050{,}310 + (17{,}337 \times 20)}{40}$$

$$= \frac{1{,}050{,}310 \times 346{,}740}{40} = 34{,}926 \text{ board feet.}$$

(*c*) *Value and Application*, — This is a very simple and accurate method of gauging the allowed cut in even-aged forests of only moderate regularity, the very conditions so frequently encountered in America. Hufnagl suggests that current annual increment can be used in place of mean annual increment in the calculations, but the latter is the more conservative and hence its use is to be preferred. Where yield tables are lacking, the mean annual increment can be approximated by measuring average stocked sample stands whose age is close to *r* years. This method combines area and volume, and, if supplemented by a careful cutting plan, will serve every purpose of regulation.

103. Summary of Results by Different Methods. — Using the same premises for computations, the allowed annual cut is as follows:

Article.	Method.	Premise.	Premise.
Number.		White pine forest even-aged. Area = 100 acres. Rotation = 80 years.	Hardwood forest uneven-aged. Area = 1730 acres. Rotation = 160 years.
98 99	Area	1.25 acres (not expressed in board feet.)	43.25 acres = 147,050 board feet.
100	Von Mantel	32,708 board feet	110,071 board feet
100	Heyer	39,479 board feet	106,188 board feet
101	Swiss	....	113,954 board feet
101	Hufnagl	....	164,614 board feet
102	Area and volume (Hufnagl)	34,926 board feet	....
	Average	35,704 board feet	128,375 board feet

104. Selection of Stands to be Cut. — A hundred years ago, Cotta, one of the greatest of all foresters, said: "A proper division of area, orderly sequence in cutting, and frequent revision of the working plan, are far more important than a mere calculation of the permissible amount of timber to cut." This is as true today as it was a century ago. Division of area has been dealt with in Article 81. Revision of the working plan will be, in Article 110. There remains the sequence of cutting, that is, the selection of stands to be cut, which, in its highest form, leads to the establishment of cutting series.

The conditions which govern the selection of stands to be cut are: market, maturity, damage (insects, fungi, etc.), windfall, fire, and the like.

Under market are contained all the manifold considerations of logging accessibility, of profit in cutting and marketing, and the sizes and species which can be logged. For example, a spruce stand on top of an isolated mountain like Mt. Graham in Arizona may be fully mature and in need of cutting, but unless there are adequate logging devices which can market the timber at a reasonable profit, it is useless to designate this as the sole cutting area of the next working period, that is, the period of years during which the working plan is intended to apply.

105. Cutting Series. — A cutting series, or felling series, is an aggregation of stands into a proposed or actual sequence of felling areas — that is, areas on which the trees have been cut or are to be cut. The object of such a series is a distribution of felling areas for administrative reasons or to secure a final satisfactory distribution or location of age-classes, especially to avoid damage by windfall and insects due to uniformity of stand and size of felling area. It is intended to interrupt a regular sequence of age-classes. It is quite generally used abroad in spruce to prevent windfall and in pine to prevent insect damage. It is not used in broadleaf forests or in any selection forest.

An example of cutting series is shown in the frontispiece. Cutting series must be planned decades in advance, and require careful thought and accurate judgment. The cutting of such a series requires many years and early mistakes are difficult to correct. Although cutting series find but little application in American practice today, the underlying principle can be utilized now.

106. Plan of Cutting. — Having determined "how much" and "where" to cut during the ensuing working period, this is reduced to documentary form in the plan of cutting.

Two kinds of cutting plans are generally prepared: a *general cutting plan* for the entire working period — *i.e.*, for the period of years during which the working plan is intended to apply, usually 10 years; and an *annual cutting plan* for the ensuing year.

The general cutting plan provides cutting areas sufficient to yield (if the working period be ten years) at least ten times the volume of the allowed annual cut, or ten times the area, as the case may be. It should, however, provide for somewhat more, so as to furnish additional cutting areas in case it proves to be impracticable to cut certain areas or in case a higher cut is possible than was originally intended.

For the annual cutting plan, the administrator, through his intimate knowledge of the forest and of local conditions of logging, market, etc., selects from out the general cutting plan those areas which, in his judgment, should be cut during the ensuing year.

As an example of the plan of cutting, the selection forest of hardwoods in the Catskills will serve. According to Article 103, the allowed annual cut, on the 1730 acres of slope type, figured by five different methods, averages 128,375 board feet. Assuming a working period of ten years, this would allow a cut of 1,283,750 board feet in the next decade. In order to be conservative, the cut for the decade would be set at 1250 M. feet., b.m., which should not be exceeded by more than 10 per cent. This fixes the "how much;" the "where" is determined by a careful examination of the individual blocks and shows that cutting should begin in Cascade Block.* The block description for Cascade shows a total stand of 3,212,288 board feet, of which 67 per cent is over the assumed limit of 16″ d.b.h.† and hence to be cut. This would make available 2,152,233 board feet, more than enough for the cut during the first decade. It is neither necessary nor advisable to consider any additional increment which may accrue during the working period; such corrections may best be left to frequent revisions of the working plan at regular intervals. In this case, at the end of the decade a thorough revision of the working plan and new growth data will doubtless warrant a largely increased annual cut.

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* See map facing page 166.

† Table 5, Bul. 11, Conservation Commission, Albany, N. Y.

107. Plan of Planting. — Some planting operations are necessary in every well-regulated forest, whether it be to eke out a too scanty natural reproduction or to re-stock former forest areas where natural reproduction is out of the question.

Just as a general cutting plan is drawn up for the intended cuttings in the ensuing working period, so a *general planting plan* is drawn up to cover all the operations of artificial reproduction which are contemplated during the ensuing working period. From out this general planting plan the man in charge of the forest selects those areas whose re-stocking he deems of the most immediate importance and incorporates them into an *annual planting plan* which becomes the planting schedule for the ensuing year.

As a preamble to the general planting plan there should be a general discussion of the areas needing artificial reproduction, the extent to which it is expedient to go in re-planting commensurate with the results to be obtained, and other phases of the policy to be pursued in the choice of areas. This should be followed by a full discussion of the species and the methods of seeding or planting to be employed. First the results of past plantings and sowings, accentuating the reasons for failure or success, and then the policy for future planting and sowing. The source of plant material — seeds, seedlings, and transplants should be considered; the seed should be shown to be from reliable and appropriate sources (sources suitable to the climatic and site conditions), and the planting stock preferably grown in nurseries on the forest or else secured from outside nurseries whose site corresponds approximately to that of the intended planting area. If there are to be nurseries on the forest, the preamble of the general planting plan gives full provisions for their location, creation, and maintenance, and should contain the area thereof in seed-beds and their capacity, the area thereof in transplant beds and their capacity, and the proposed annual production by species and classes of stock.*

The area which it is intended to plant or sow during the coming working period should be indicated on the working map of the forest either by color or shading or symbols.

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* For details of practice see "Seeding and Planting in the Practice of Forestry," J. W. Toumey, John Wiley & Sons, Inc., 1916. For a Planting Plan Outline, see the Appendix, page 244.

CHAPTER XIV

THE WORKING-PLAN DOCUMENT

108. Contents and Form. — The working-plan document is the vehicle for recording the salient features of a forest bearing on its organization and the detailed prescriptions of that organization for the next working period. Simplicity and brevity are the key-notes. The descriptive portion is usually confined to such short statements as suffice to bring to the trained forester's eye the picture of the forest as it is in its essentials, but, occasionally, a more detailed description is warranted so as to make the plan comprehensible to a layman, *e.g.*, where the plan is to be executed by a layman-owner.

In the interests of clearness and brevity data should be tabulated wherever possible, *e.g.*, estimates, stand tables, age-class tables, etc. Maps, also, are a powerful aid in graphic presentation of the data.

The working-plan document may be confined to the silvicultural management, or it may cover all the activities of a forest such as general administration, grazing management, permanent improvements, forest protection, and use of forest land; in other words, be a complete forest plan. The desirability of including these sundry subjects depends on their importance and the purpose of the plan. National forests usually require complete plans. Where other subjects than that of silvicultural management are to be included, the descriptive data preceding the plan proper must be amplified accordingly.

These essentials may be presented in various forms, varying with the needs and desires of the administrative officers. The form of the working-plan document is comparatively unimportant. It may be typewritten or not, bound or unbound. If typewritten it can be manifolded more easily; if plainly bound it resists handling better, and the working-plan document is meant to be used constantly, not put away on a library shelf for the admiration of visitors. To facilitate this use a 2-inch margin should be left at the side of the text throughout the document, excepting tables, for the purpose of allowing notes to be made from time to time by persons charged with the execution of the plan. This simple device keeps a plan alive and up to date and greatly facilitates the work of revision.

The field-work in connection with forest organization often results in the collection of many interesting and valuable silvical and other data which, while germane to the working plan, are not a cognate part thereof. Such data, including volume, growth, and yield tables, silvical notes, notes on climate, geology, soil, etc., should be placed in the appendix or elsewhere convenient, in order that everything in the plan may be confined to the actual scheme of management for the forest.

109. Outline for Working Plan. —

1. *Introduction.*
   - *a.* Location and size of forest (working unit).
   - *b.* History of forest with important changes.
     - (1) Past and present ownership (status).
     - (2) Boundaries. Interior surveys.
     - (3) Past object of management and general administration.
     - (4) Past revenues and expenditures.
   - *c.* Physiographic features.
     - (1) Topography.
     - (2) Drainage.
     - (3) Geology (formation).
     - (4) Soils (depth, fertility, etc.).
     - (5) Climate (maximum, minimum, and average temperature, rainfall, prevailing wind direction).
   - *d.* Social and industrial features.
     - (1) Population. Dependence on forest for work and fuel and timber supply.
     - (2) Labor supply.
     - (3) Local conditions — lumbering, grazing, mining, agriculture, etc. Interrelation with forest.

Notes to amplify and explain outline:

I. INTRODUCTION

(a) **Location and Size.** — The briefest mention suffices.

(b) **History of Forest with Important Changes.** — Past and present ownership and administration, boundaries, past object of management, past revenues and expenditures.

(c) **Physiographic Features.** — The physiographic features include topography, drainage, geology, soils, and climate. Detailed observations and statistics should be reserved for the appendix, and only the salient characteristics which influence the forest organization stated briefly.

(d) **Social and Industrial Features.** — The social and industrial features include population, labor supply, local industries such as lumbering, grazing, mining, agriculture, etc., all in their bearing on the problems of forest organization. For it is evident that without adequate labor no forest resources can be developed, without lumbering facilities no regulation of the cut can be maintained or executed, and the very term "accessible" is modified by the degree of skill exercised in logging and the kinds of appliances used to get the timber. Again, the need of the local population for timber is the root of the theory of sustained yield. These fundamental phases require no detailed discussion, but brief statements of conditions in explanation of the plan proper.

e. Digest of working-plan conference.

f. Time, method, and personnel of field-work. Cost, if desired.

2. *Foundation.*

a. Growing stock (estimates). Tabulation. (Stand and stock tables if uneven-aged.)

b. Increment per acre or per cent or both.

c. Distribution of the age-classes. Tabulation. (Diameter-classes if uneven-aged.)

d. General stand table. Tabulation.

(e) **Digest of Working Plan Conference.** — If a conference was had between the forest organizer and the owner or administrator of the forest, as suggested in Article 84, this should be digested and added to the working-plan document with the names of the participants.

(f) **Time, Method, and Personnel of Forest Survey and Organization.** — These statements should be exceedingly brief — a tabular form is advisable for time and personnel, since they are of purely historical interest. The method used should, however, be set forth in sufficient detail so that there can be no question as to how much weight attaches to the accuracy of maps and estimates.

2. FOUNDATION

(a) **Growing Stock (Estimates).** — The estimates should be in form of a table by species and classes of timber, either separate stand and stock tables or as part of the general stand table. The details of this estimate table depend on the intensity of the entire plan. It will usually suffice to give the totals by compartments (if any) and blocks, or else by survey units such as sections, or even townships. Separate estimates may be given for each forest type. The estimate for the entire working unit must always be given. It must also be stated to what minimum diameter trees were estimated and, if available, what average deduction must be made for defect. Estimates in greater detail, *e.g.*, section sheets showing the stand on each "forty," should be reserved for the appendix or for the files. Volume tables should be placed in the appendix.

(b) **Increment.** — The increment, either current or mean annual, or else both, is given, and is expressed either in increment per acre or as a per cent or both. Growth and yield tables on which the calculation of increment may be based should be included in the appendix.

(c) **Distribution of the Age-Classes.** — If the stand is even-aged or approximately so, a table of age-class distribution, like Fig. 25, should be included. Not only does such a table show at a glance the relation of young, mature, and overmature timber, but, in the revisions of the working plan, it shows by means of graphs or blocks what progress has been made toward the attainment of normality in this direction.

(d) **General Stand Table.** — This should be included as a convenient tabular summary of areas, volumes, and conditions of timber.

e. Maps. Statement of maps prepared. The maps themselves should go in the back of the plan or else be kept on file separately.

(e) **Maps** can be elaborated to almost any extent according to the kind and importance of the data to be shown thereon. The following are the most important:

(1) A *topographic map* showing topography in contours, seldom hachures; roads, trails, railroads, saw-mills, and all other "culture;" drainage. This map is the "base" and should be of a convenient scale, such as ½, 1, 2, 4, or even more inches to the mile, depending on the size of the tract and the amount of detail to be shown. It should be drawn so as to permit of being manifolded in order that all officers charged with the administration of the forest and the execution of the working plan may be furnished with copies. On this "base" can be added any or all of the following special data in so far as the wealth of detail will not confuse the whole.

(2) *Boundary map* showing the ownership (status), the forest boundary or boundaries; survey lines, if any; boundary or boundaries of the working units, blocks, compartments, and sub-compartments.

(3) *Forest-type map*, showing the various forest types, also cut-over areas, burns, open "parks," etc.

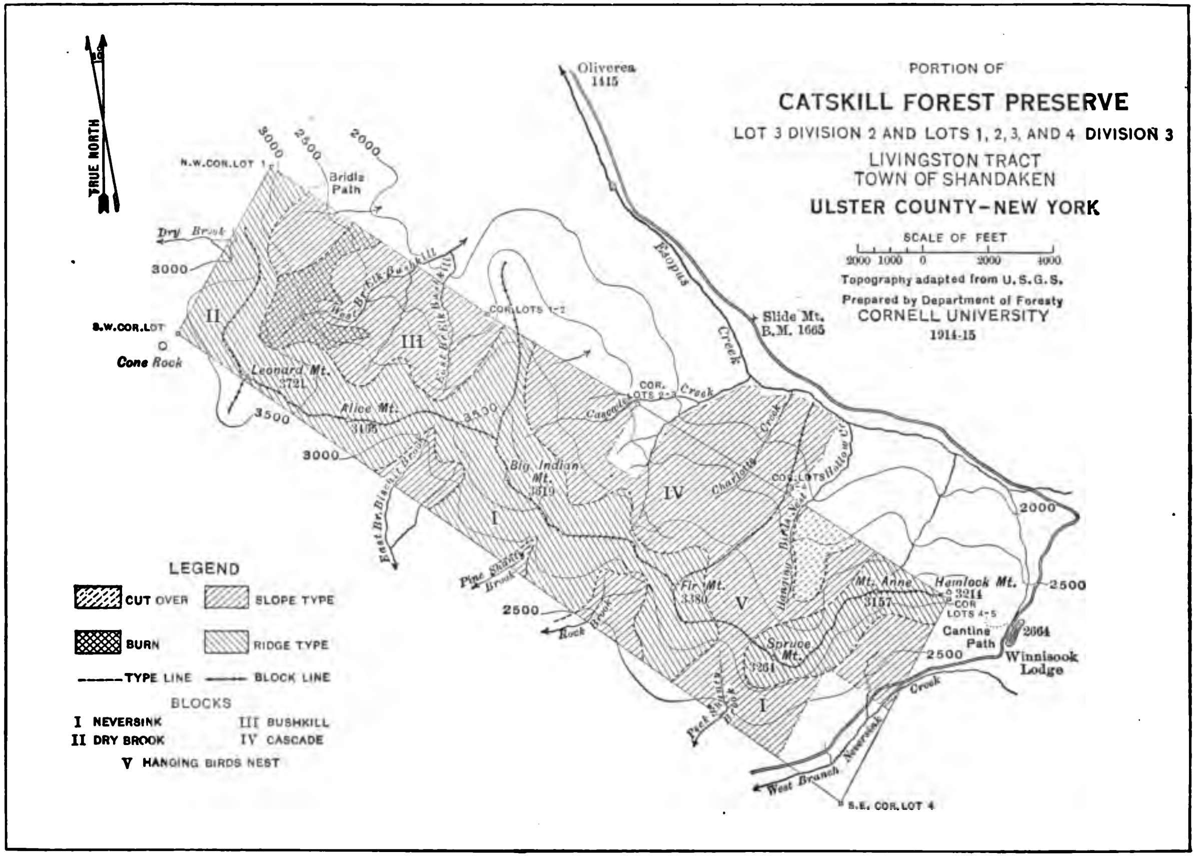
(4) *Age-class map*, showing the distribution of the various age-classes on the ground.

(5) *Site-quality map*, showing the distribution of the various site qualities.

(6) *Soil map*, showing the various soils and geologic formations of the forest.

(7) *Reproduction map*, showing areas of good, fair, and poor reproduction.

(8) *Cutting map*, to accompany the general cutting plan, showing areas to be cut over within the next working period, also those already cut over.



Forest Management Map — Showing topography, boundaries, types, and division of working plan unit into blocks.

(9) *Planting map*, to accompany the general planting plan, showing areas to be re-stocked artificially during the next working period, and areas already planted or sown, all nurseries and proposed nursery sites.

(10) *Fire map*, to accompany the fire plan showing all lookout points, watch towers, lines of patrol, ranger headquarters, fire-guard stations, location of fire-fighting tools, and places whence assistance in fighting fire may be obtained. The base should be maps 1 and 3 combined.

(11) *Permanent improvement map*, to accompany the permanent improvement plan showing all improvements, existing or proposed, such as ranger stations, fire cabins, telephone lines, etc.

(12) *Grazing map*, to accompany the grazing plan showing the grazing types, condition of the range, the portions grazed (and by what class of stock) or ungrazed, the winter, summer, or year-long range, corrals, pastures, drift fences, water tanks, etc.

Lest too many data be placed on one map, it is better to have separate maps than to combine too much and cause confusion.

Detailed maps of survey units or of small areas which it is desired to show in greater detail should be placed in the appendix, as should also special maps showing areas of insect or fungus attacks, etc.

f. Forest description. (For outline see Appendix, page 243.)

g. Division of area. Working unit, block, compartment, sub-compartment. Working group if necessary.

3. *Recommendation.*

a. Object of management. Wishes and purpose of the owner (policy, if national or state forest). Exploitation or sustained yield (annual, periodic). Production of cordwood, saw-timber, pulp-wood, turpentine, etc.

b. Practical restrictions. Market, logging accessibility, special danger from fire, erosion, avalanches, etc.

(f) **Forest Description.** — Must be concise and free from burdensome details. Silvical details, methods and costs of logging and milling, etc., had better be placed in the appendix or in a special file. The forest description of the entire working unit should be a careful summary of the description for each block. The aim is to present a lucid picture of the forest as it is in the essential silvical factors bearing on the plan of management adopted. The description must be ample reason for the provisions of the working plan. The description is the premise; the recommended management the logical deduction from that premise.

(g) **Division of Area.** — On the basis of the forest description, the division of area should be so evidently logical as to require very little special justification. However, it is well to explain briefly what considerations governed in the choice of working unit, block, compartment, and sub-compartment, in so far as this was not already covered in the digest of the working-plan conference. Since the working unit usually has a sustained yield, its adequacy from this viewpoint should be considered along the broad lines already laid down.

3. Recommendation

The recommended management should be the logical sequel of the data given under "Introduction" and "Foundation." The basic considerations of object of management, of silvicultural method of management, and of rotation are contained in Chapter XII. This part of the working-plan document should review the governing conditions which determine the recommended management. These are:

(a) **Object of Management.**—*i.e.*, the wishes and purpose of the owner (in so far as not already contained in the digest of the working-plan conference).

(b) **Practical Restrictions** of market, logging accessibility, fire danger, erosion danger, etc.

c. Silvicultural method of management.
  (1) Silvicultural method or methods, their proposed application.
  (2) Rotation (period of reproduction, cutting cycle, etc.).
  (3) Marking rules.
  (4) Rules for brush disposal.

(c) **Silvicultural Method of Management** which can best fulfill the object of management with the given silvical conditions and under the practical restrictions imposed. Past management and its mistakes and lessons should be reviewed and the proposed method of management given in detail. The best silviculture is not always possible under existing conditions, and the organizer must seek to combine the three divergent factors of object of management, practical restrictions, and silvical requirements into a harmonious scheme of management. This should cover:

(1) *Silvicultural method* for each type with brief description thereof.

(2) *Rotation* chosen, with reasons for its adoption. The period of reproduction, cutting cycles, etc., should be given and made entirely clear.

(3) *Marking rules* to be followed in the execution of the cuttings for natural reproduction. They should be clear and concise, simply put so as to be readily intelligible to the non-technical man charged with their execution, sufficiently elastic to cover all cases. Good marking rules will do much toward insuring the actual execution of the silvicultural method decided upon, especially when backed by sample areas marked by the forest organizer as a concrete illustration.

(4) *Brush disposal rules* are a necessary concomitant of the marking rules. Here too actual examples of what is desired should reinforce the written rules.

4. *Regulation.*
  a. Determination of cut.
  b. Distribution of out. Formation of cutting series, etc.

c. General cutting plan for working period.

d. General planting plan for working period.

5. *Administrative plan.*

a. Scheme of field administration.

(1) Administrative districts and area.

(2) Field and office force, year-long and temporary.

b. Forecast of receipts and expenditures and net income for working period.

4. REGULATION

As the recommended management (3) is the logical outgrowth of the data given under Introduction (1) and Foundation (2), so the regulation of the cut itself is but the carrying out of the Recommendation (3).

The chief phases of regulation are:

(a) **Determination of the allowable cut** by one or more of the methods already described. Where working groups are formed, each requires a separate determination of the cut.

(b) **Distribution of the Allowable Cut.** — Selection of stands to be cut, formation of cutting series, etc., with concise reason for the choice; cutting policy in so far as not covered already in the digest of the working-plan conference.

(c) **General Cutting Plan** for the next working period. It should contain recommendations in regard to stumpage rates, methods of logging, rules of cutting to prevent waste, and other features of practical utilization such as probable purchasers, uses and markets, etc. An annual cutting plan for the ensuing year is usually drawn up by the administrative officer in charge of the forest, and does not, as a rule, form a part of the working-plan document.

(d) **General Planting Plan** for the next working period according to the outline given in the Appendix (page 244). A description of the methods and cost of nursery, planting, and seeding practice to be employed. An annual planting plan for the ensuing year is usually drawn up by the administrative officer in charge of the forest, and does not, as a rule, form a part of the working-plan document.

5. ADMINISTRATION

(These and subsequent notations are taken from the U. S. Forest Service outline for Working Plans.)

Administrative districts. Number, area, and relative importance or amount of work. (Tabulate.)

Force. Office and field and assignment. Salaries.

Also a brief forecast of future requirements. (Tabulate.)

Permanent, statutory.

Semi-permanent and temporary.

General administrative policy of forest. (General relation of important lines of work. Include also points not already covered; fully and briefly in 1, 2, and 3 order.)

Receipts and expenditures and results. By lines of work for fiscal years, past and estimated future.

Administrative provisions for increasing receipts or reducing expenditures.

Map, boundaries of administrative, or other districts.

6. *Grazing plan.*
   - *a.* Description of forage types and condition of range.
   - *b.* Protection and development of range.
     - (1) Range improvements. Watering facilities.
     - (2) Treatment of overgrazed and partly stocked areas.
     - (3) Measures for fuller use of range.
     - (4) Control and eradication of poisonous plants.
     - (5) Control and extermination of predatory animals, prairie dogs, and other pests.
   - *c.* Grazing control. Capacity of range. Grazing districts and allotments.

6. GRAZING

Range Management:

Types. (Concise descriptions of each.)

Names of important and characteristic forage plants.

Accurate data on seasons of growth.

Accurate data on forage value.

Acreage. With forage. Waste. (Tabulated.)

Carrying capacity. Present. Possible. Brief descriptions. By allotments or divisions. (Tabulated.)

Demand and other local conditions in the live-stock industry which affect grazing on the forest. Relation to silviculture.

Allotments.

Arrangement. (Division of the range between cattle and sheep, grazing districts, and individual allotments to be shown on map. Guiding principles, or necessary comment in the discussion.) To secure:

Best division between cattle and sheep.

Full and equal utilization.

Best division of types and early and late ranges.

Best division of watering places.

Proper silvicultural and watershed protection.

Number and kind of stock grazed. By allotments or divisions. Number of permits by classes.

Seasons. (To secure full utilization of the forage without seriously interfering with the natural requirements of plant growth, each portion of the range should occasionally, every few years, be grazed only during the last half of the natural growing period in order to keep the plant constitutions strong and allow some actual reseeding. So far as is consistent with this principle, the green tender feed should be available for the stock during as much of the season as is practicable. This is essential, especially for sheep. This plan may be considered a variation of seasons or a division of allotment.)

Fees. By classes of stock and season. (Tabulated.)

Methods of handling stock.

Cattle. (Salting and necessary riding by permittees to secure equal utilization of range and prevent congregation along streams and water holes, with resulting destruction of plant growth and poor development of stock.)

Sheep.

Size of bands.

Herding. (Develop open quiet herding and avoid driving back to camp.)

Salting. (Encourage abundant use of salt, it means easier herding, less danger from poison and disease, and less damage to the range.)

Other stock. (When special provisions are required.)

Range improvements:

(Permanent improvements in the improvement section.)

Re-seeding either with cultivated plants or by restricting grazing for natural re-seeding, posting poisonous areas, changes or improvement in stock driveways, extermination of predatory animals, prevention of erosion by proper handling of stock.

Policy and administration.

General principles of policy not already covered. Protective and maximum limits, new owners, advisory boards, etc.

Administration. Extermination of predatory animals, counting stock, or other special phases of the work. Special force required. Costs.

Investigations:

Proper seasons, carrying capacity, poisonous plants, artificial re-seeding, demonstration tests of proper utilization, effect of grazing upon reproduction, and most efficient systems of grazing management to eliminate damage. Herbarium with necessary notes.

Map or maps, showing types, water, fences, corrals, topography, grazing districts, allotments, reserved areas, driveways, or other factors or features which influence or illustrate the handling of the stock.

7. *Permanent-improvement plan.*
   - *a.* General.
   - *b.* Telephone.
   - *c.* Look-out towers.
   - *d.* Fire cabins and tool-boxes.
   - *e.* Roads and trails.
   - *f.* Ranger stations.
8. *Forest-protection plan.*
   - *a.* Fire control.
     - (1) Nature of fire problem.
     - (2) Past fires. Bearing on the plan.
     - (3) Hazards. Danger zones, extra fire risks, necessity of special measures.

(4) Coöperation. Desirable and proposed coöperation.

(5) Scheme of protection.
  (*a*) Primary control by look-outs.
  (*b*) Secondary control by patrol and actual combat.

(6) Organization. Look-outs and patrolmen. Action in case of fire.

(7) Mobilization.
  (*a*) Fire-fighters, regular and volunteer, available.
  (*b*) Transportation. Logging railroads, pack-trains, teams, etc.
  (*c*) Tools, equipment, and supplies. Location of tool-boxes. Bases of supplies.

(8) Improvements. Additional headquarters, telephone lines, trails, etc., required.

7. PERMANENT IMPROVEMENTS

Improvements. Comprehensive plan of the improvements needed. Location, brief description, estimated costs, indicate those which should be undertaken within the next five years. (Tabulated form.)

  Roads, trails, telephone lines; fire lines, administrative fences, stock fences, including the fencing of poisonous areas and bog holes, bridges, corrals, dwellings, other buildings, water development, stream improvement, dams to prevent erosion, other projects.

Maintenance, as above.

Policy and administration.

  Improvement policy of the forest. (Concisely by lines of work such as silviculture, grazing, protection, general administration, etc.)

  Administrative provisions. Special force needed. Costs, exclusive of the costs of individual projects.

Map showing all improvements constructed and planned, with a sufficient amount of other data to make intelligible.

8. PROTECTION

Fire: (By divisions or geographical subdivisions, if advisable.)

  Liability. Statement of value of destructible resources by classes, and for districts or regions.

    Timber, expectation value of young growth, forage.

    Arbitrary value per acre of watershed protection. (Possible money damage. Tabulate.)

  Hazard or risk. Statement by types or regions based upon character of stand, danger of fires starting, and difficulty and cost of suppression. (Should be based in part upon a study of past experience.)

- Protection required. (Principles which sum up on the basis of liability and hazard; the relative amount of protection needed in specified parts of the forest.)
- Control.
  - Improvements available. By districts. (Brief description, tabulate if map is not sufficient.)
  - Communication. Telephone, etc.
    - Transportation. Railroads, roads, trails, pack trains, etc.
    - Fire lines.
    - Look-out stations.
  - Supplies and tools. (Distribution or how they are to be purchased, etc. Tabulate.)
  - Coöperation.
    - Adjoining forests, between ranger districts, State associations, corporations, individuals, etc.
  - Organization and administration.
    - For look-out stations and patrol. Numbers of men and duties by districts. (Tabulate so far as possible.)
    - For fighting fires. (Tabulate if possible.)
      - Regular and temporary force.
      - Coöperation, labor, including users.
      - Outside labor.
    - Costs.
  - Specific and detailed instructions to rangers based on the above, and resulting in its direct application should be issued to all forest officers engaged in fire protection.
  - Map showing types, topography, improvements, and as much of above information as is possible and advisable. Copies to accompany letters of instruction.

b. Insect control } and other special problems warranting inclusion.
c. Fungus control }

9. *Uses of forest land.*
   - *a*. Settlement.
     - (1) Classification of lands, whether of relatively greater value for agriculture or for forest purposes.
     - (2) Sale prices of land. Comparative land values.
     - (3) Cost of clearing land for agriculture and probable profits of agriculture thereon.
   - *b*. Special uses.
   - *c*. Water-power sites. Present and future development. Stream measurements.

Insects:

- Extent of infestation and damage.
- Control, administrative measures, methods. Special force needed. Costs.

Other damages:

Extent. Amount of damages.

Control, administrative measures. (As under Insects.)

Game:

Policy and administrative measures.

Investigations:

9. LANDS

Settlement:

Soils. (Classification with brief description and a statement of comparative agricultural and forest value of each class based upon land values, forest expectation values, etc.)

Demand for agricultural lands. Past, present, and future.

Policy. (In 1, 2, and 3 order, application of policy based upon the preceding classification, results of past policy, service policy, and any other principles as a guide to examiners. Practicability of detailed classification of certain districts in advance of application.)

Map, showing soil classification, if data is available.

Uses and Easements:

Resources.

Demand. Past, present, and future.

Policy. (Special features which are important by kinds of uses or easements. Include charges compared with value to users.)

Water-power:

Resources. Streams, sites, power. Cost and market data and stream measurements. (Tabulate.)

Demand. Past, present, and future.

Policy. (Special features.)

Administrative sites:

Sites, rights of way, etc., withdrawn, or still needed and to be withdrawn. Include comprehensive plan of rights of way needed for future sales and other uses as well as sites and rights of way required in administration. (Tabulate or show on map.)

Administration:

Special force needed. Other administrative questions.

Costs.

Investigation:

Map or maps showing status, location of uses, easements, water-power projects, administrative sites, etc.

10. *Appendix* (observations not properly a part of the main working plan).
    - *a.* General data — geology, soils, climate, occurrence and protection of fish and game.
    - *b.* Silvical data.
        - (1) Volume, growth, and yield tables.
        - (2) List of component species.

- (3) Silvical characteristics of component species.
    - (*a*) Soil and moisture requirements.
    - (*b*) Influence of elevation and aspect.
    - (*c*) Tolerance.
    - (*d*) Reproduction.
    - (*e*) Injuries: fire, storm, frost, drought, fungus, insects, etc.
- *c*. Detailed estimates, maps, forest descriptions, etc., of survey units or other units, unless filed elsewhere for greater convenience.

10. APPENDIX

Material which should be preserved in connection with the plan, but which will be used infrequently in actual forest administration.

List of species.

Details of methods used in the collection of data, costs, and areas covered.

Tables, growth, volume, etc., when it is reasonably certain that they will be used infrequently.

Details of method for regulating the cut.

Detailed silvical discussions upon which conclusions and principles outlined in the plan are based, if preservation seems necessary or advisable.

General notes upon which the conclusions in the plan were based.

Inventory of existing improvements, if desired. (Tabulate.)

NOTE. — In addition to the general working plan, annual or periodic plans may be based on the general working plan and may refer to any specified class of work, as the annual cutting, planting, protection, grazing or administration and improvement plan. Such annual plans may be either mere schedules or may contain more or less detail, explanations, estimates of cost and results, as seems desirable.

110. Control and Revision. — No working plan can remain alive and useful unless it is revised at frequent, more or less regular intervals. These revisions incorporate all the changes which have taken place during the working period. Such renewals may be made at fixed intervals of say ten years or at irregular intervals as is commonly the case where revised data or changes in prevailing market conditions, etc., necessitate modification of the original plan.

Since the working period is usually ten years, the working-plan document is usually revised every decade. But under very intensive conditions more frequent revision may be justified, even to the extent of every five years. On the other hand, a plan should not, ordinarily, go without revision for more than a decade, even though the working period be longer.

Especially under the kaleidoscopically changing conditions in most parts of America is it desirable to have frequent revisions so that the working plan may really "work" and not become obsolete within the working period. Special revisions before the end of the working period are, of course, necessitated whenever, through storm, purchase, or the like, a substantial change is caused in the size, character, or composition of the forest.

The record of the progress of the work on the forest as outlined by the working plan is called the working-plan control. This control operates as a check on the execution of the working plan. In European practice these records are kept by maps and books. The entries are made periodically or at the time of completing each of the various projects. The books (called "control books") may conveniently be divided into two parts: I, the cutting and planting record; II, the general or "history" book.

It is obvious that this part I of the control book is built up from the annual cutting and planting plans. It embodies their essentials in convenient form as a permanent record. It can, of course, be extended to cover all the activities of the forest besides "timber," *e.g.*, grazing.

A separate page is kept for each convenient unit — be it block or compartment, township or section, depending on the needs of the administration.

All areas cut or planted are to be entered on the map of the forest.

Part II, the "history" book, contains convenient headings for a general record of the various forest activities. Such are:

1. *Forest survey and boundaries:* a running record of the forest surveys made and proposed, be it for timber, grazing, or what not, and of the changes in boundaries and the demarcation in the field of the boundaries.*

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* This may also include the Status Records, that is, records showing the ownership of newly acquired lands. Complete status records will show in detail the

2. *Methods of cutting and planting:* a running record of silvical observations in natural and artificial reproduction.

3. *Forest protection:* a running record of all important forest menaces; the method and success of the combat with them. Such are:

(*a*) Fire.
(*b*) Storm.
(*c*) Frost.
(*d*) Drought.
(*e*) Fungi.
(*f*) Insects, etc.

4. *Administration.*
5. *Grazing.*
6. *Permanent improvements*
7. *Uses of forest land.*
8. *Utilization of forest products.*
    (*a*) Methods and costs of logging.
    (*b*) Methods and costs of saw-milling.
    (*c*) Markets and prices of stumpage and lumber or other products.
    (*d*) Utilization of by-products.
    (*e*) Impregnation of wood (wood preservation), etc., *ad lib.*
9. *Fish, game and the chase.*
10. *Money returns of management.*
    (*a*) Gross income and expense.
    (*b*) Net income.
11. *Personnel relations.*
12. *Miscellaneous data.*

Such a control book, together with the summarized annual cutting and planting plans, corrected maps, and the marginal notes and corrections in the plan itself, forms a perfectly adequate basis for undertaking the periodic revision.

chain of title for each parcel of land and also all servitudes and easements attaching to the land. In addition, they usually show the location and extent of all qualified or temporary alienations such as unpatented mineral claims, leased areas, or lands otherwise specifically under permit or affected by outstanding contracts, as for the sale of timber, etc.

The thoroughness of the revision depends on the correctness of the original plan. Only rarely should it be necessary to re-write the entire plan. Those portions which come under "introduction," such as physiographic features, social and industrial features, and under "foundation," such as forest description, division of area, etc., can either be incorporated directly in the new working plan, or else reference made to the original working plan covering these subjects in detail.

In matters of determination and distribution of the cut as embodied in the general cutting and planting plans, the revision is essentially a re-calculation and re-allotment.

The preliminary of every revision should be a working-plan conference to review the plan for the working period just passed and to make suggestions for the ensuing period. The digest of this conference should be incorporated in the revised working plan.

CHAPTER XV

FOREST FINANCE

111. Definition. — *Forest finance* is that part of forest management which relates to the forest as an investment. It includes two distinct subjects: forest valuation and forest statics; the first concerns itself with valuations of soil and growing stock, increment and damage; the second concerns itself with a comparison of the financial results of different methods of treatment and other questions of profitableness and financial effects.

Forest finance calculations require a clear understanding of the terms: *Value*, *Capital*, *Cost*, and *Income*.

112. Value. — The following values may be differentiated:

Investment value. — The purchase price or the actual expenditure or investments that have been made in acquiring or creating the property with interest, less incomes actually derived from it, with interest.

Cost value. — An investment value based on production. This may be differentiated into — *Subjective cost value* if based on actual expenditures, and *Objective cost value* if based on estimated cost of replacement of the property (as in damage suits).

Sale or Exchange value. — The market price based on statistics of actual sales; a special kind of sale value is the *forced sale* or *wrecking value* that can be obtained by exploitation of saleable parts.

Stock or Stumpage value. — Based on sale value of material ready for immediate utilization.

Expectancy value. — The present worth of all estimated or expected future net earnings (discounted value); the capitalized net income value.

Rent or Yield value. — A value, determined by capitalizing, with a demanded rate of interest, the yearly or intermittent net return possible to be derived from a managed property. *See* Forest Rent and Soil Rent, Article 94.

113. Capital. — This factor of production in the forestry business is variously figured according to what parts of the investment are referred to and what basis of valuation is applied.

Fixed capital — refers to such kinds of capital as are not used up in production, like the soil.

Working or *operating capital* — refers to money capital needed to supply current expenses in operating a forest.

Soil capital — refers to the value of the soil figured in various ways.

Stock capital — refers to the value represented by the wood material of all stands comprising a forest or working unit.

Forest capital—refers to soil capital and stock capital combined.

Base capital — may be used for the combined soil and working capital.

These capitals may be based upon various kinds of values, and to secure a definite meaning, the term must be qualified by the method by which its value was determined.

There are four sources of capital which may in a greater or less degree be relied upon for *large scale* forest production, viz.:

1. The nation.
2. The state.
3. The municipality.
4. The large corporation.

114. Cost. — In Article 77 it was pointed out that the requirements for a sustained yield management are five-fold.* So are the costs per acre of growing timber dependent on five main factors:

1. Interest on the value of the land.
2. The cost of stocking it with young trees and interest on this amount from time of stocking to maturity.

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* 1. Enough, accessible forest.
2. A forest of the right character so that it will pay to cut it for repeated crops.
3. Adequate fire protection.
4. Equitable taxation.
5. Good markets for products.

3. The annual expenses for administration and protection and interest on each annual expense from time of expenditure to time of maturity of timber.
4. The annual taxes and interest on each annual tax from time of payment to maturity of timber.
5. (Last but not least!) The rate of interest.

How do these factors affect various classes of owners?

Certain owners might save all or portions of certain costs, or find them properly chargeable to other lines of business which they conduct. Thus a coal mining company might find it necessary to hold a large area of coal lands, the surface of which is unsuited to agriculture or any other use except forestry. In this case it would be fair to charge all the land value to the coal, thus removing the heavy interest cost on land value from the forestry costs. This would enable a company of this sort to produce timber as cheaply as the state.

In *municipal* forestry, a city finding it necessary to own land for watershed protection might practice forestry without charging interest on land value to it, and might also charge a large part of the actual administration cost to the water department because sanitary patrol is necessary anyway. (Example: area around Ashokan Reservoir, New York.)

The *large corporation* can practice forestry because of its relatively low interest rate and the economies in administration and protection due to the ownership of large areas. Where it has holdings in several localities its fire losses will not exceed the average losses of the community.

Railroads have three additional advantages which would make it profitable for them to engage in forest production on lands already owned. These are:

1. They are large consumers and the cheapest possible supply of timber is of enormous importance to their construction and maintenance departments.

2. Since they are large consumers, practically all selling costs would be saved to their forestry departments.

3. Railroads depend on adjacent territory for tonnage. Land adapted only to forestry will yield little tonnage any other way,

but supposing land under management will yield 500 feet b.m. per acre per year. This would mean to the railroad from 1500 to 2000 pounds of freight for each year that the forest crop is maintained.

Small Owner. — As already stated, the small owner, either corporate or individual, can seldom afford to practice forestry except in the case of the farm woodlot owner. The farmer consumes most of the product of his own forest, thus saving all selling costs, middleman's profits, and transportation to a distance. To this strong economic position as to markets, may be added three other advantages:

1. Protection and administration costs nearly disappear.

2. Because of the small cutting areas necessary in the farm woodlot, reproduction will in nearly every case come naturally, without extra expense, provided grazing is properly restricted.

3. Though the farmer pays high interest rates when he borrows, he works principally on his own capital, on which, as a rule, he makes a very low rate of interest.

All elements of cost are profoundly influenced by the interest rate. Individuals, states, and the nation have to pay different rates. The elements of cost in a given case, Douglas fir, medium quality site on the Pacific Coast, as related to the interest rates, are proportionately as follows: *

	Interest Rate (Compound.)					
	3 per cent.	4 per cent.	4½ per cent.	5 per cent.	6 per cent.	7 per cent.
	Per cent of total due to each item.					
First cost of stocking and annual charges excepting taxes........	15	8.6	6.4	5.4	3.3	2.0
Compound interest on land value on cost of planting and administion charges (60 yr. total).......	60	66.4	68.6	74.6	81.0	85.6
Taxes and interest thereon........	25	25	25	20	15.7	12.4
Total........................	100	100	100	100	100	100

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* "The Cost of Growing Timber in the Pacific Northwest, as related to the interest rates available to various forest owners," B. P. Kirkland, University of Washington, Forest Club Annual, Volume III, 1915, pages 16–38. Reprinted in 1915. Article 114 is drawn directly from Kirkland's paper.

From the foregoing it appears that the production of timber, *i.e.*, the practice of forestry, is mainly a question of the investment of capital, either by the nation, state, individual, or some other owner. Those owners who must pay or can get high interest rates for the use of capital, cannot wisely undertake the production of timber as an investment, even if they were content with such long term investments, which is seldom the case.

Costs of Production per Cubic Foot, by Steps, in Germany. — Eberbach * shows that the total cost of producing 100 cubic feet (about 623 board feet) is $4.17 of which:

$1.31 or 32 per cent = personnel of the administration.
$1.50 or 36 per cent = cutting and marketing.
$0.246 or 6 per cent = planting.
$0.64 or 15 per cent = roads, new construction and maintenance.
$0.474 or 11 per cent = general expenses, labor, etc.
Total $4.170 = 100 per cent.

115. Income. — In forest finance, the *gross* income represents money returns from which no expenses have been deducted; *net* income results by deducting all actual expenses charged in book account, including interest on borrowed capital, but not the *calculated* interest on investment, which enters in determining *profit.*

Final income — returns from final harvest.

Intermediate income — returns from stands not yet mature.

In considering the advisability of forestry for any particular area or species, the important thing is to determine what interest rate on the capital invested can be realized on such an enterprise.

116. Compound Interest Formulæ. — There are certain problems in forest valuation for whose solution compound interest is necessary.

a. The future value of a present sum.

To compute the total cost of investment up to a definite date.

b. The present value, by discount, of a future sum.

To appraise the value of property on the basis of future income.

c. The rate of interest earned by an investment.

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* Forstwissenschaftliches Centralblatt, July, 1911, pages 357–377; Oct., 1911, pages 541–542.

For determining the ratio which income bears to the capital invested, with full recognition of the element of time.

For comparison of investments.

d. The future value of temporary annual rentals.

e. The present value of temporary annual rentals.

For these the following compound interest formulæ have been developed:

a. For determining the accumulation of cost on an investment.

Interest rate $= p$.

Principal plus one year's interest $= 1 + p$.

Interest expressed as per cent $= \frac{p}{100} = 0.0\,p$.

p is here an arithmetical, not an algebraic, quantity.

Principal plus interest $= 1 + 0.0\,p = 1.0\,p$.

At end of first year, interest is added to principal. Principal at beginning of second year $= 1.0\,p$.

Principal plus interest, end second year $= 1.0\,p \times (1 + 0.0\,p) = 1.0\,p \times 1.0\,p = 1.0\,p^2$.

By same process, at third year, $1.0\,p^2\,(1 + 0.0\,p) = 1.0\,p^3$. And in year n, $1.0\,p^n = 1.0\,p^{n-1}\,(1 + 0.0\,p)$.

$1.0\,p^n$ is the ratio which gives the future value of a present sum at p percent compound interest for n years.

Present value of capital or principal $= C$.

Value at p per cent in n years

$= C \times 1.0\,p^n = Cn$. . . . . (Formula I)

b. For discount in the valuation of assets.

Discount is the process of determining the present equivalent of a future value.

Let C_n = future sum $= 1$.

$C_n = C \times 1.0\,p^n$ from above example.

C = present equivalent at p per cent.

$C = \frac{Cn}{1.0\,p^n} = \frac{1}{1.0\,p^n}$. . . . . (Formula II)

$\frac{1}{1.0\,p^n}$ is the discount factor or multiple, a decimal, which gives present value of a future sum.

c. For rate of interest earned.

As Chapman[*] points out: "the rate of interest, p per cent, is accepted as a fixed standard in computing cost (Formula I); or in discounting for value (Formula II). But when both cost, or investment, and income are known, the ratio of this income to cost represents the earnings of the capital invested, or dividends. A rate of interest can be found by which the discounted value of income is made to exactly equal cost, or the accumulated costs to just balance income. This rate is the per cent earned by the investment.

"To distinguish this rate from the rate of interest p, the term x will be used."

The formula is:

$$1.0\,x^n = \frac{Vn}{Vo} \quad . \quad . \quad . \quad . \quad \text{(Formula III)}$$

in which x is the rate per cent of income earned, Vn the gross income, and Vo the value of all costs and charges at compound interest up to the time of cutting n.

Instead of solving these various equations, the compound interest tables in the Appendix may be used wherein Column I corresponds to Formula I, Column II to Formula II and the value of $1.0\,x^n$ may be found by interpolation in Column I.

d. For future value of temporary annual rentals.

Last payment $= e$.
Previous payment $= e \times 1.0\,p$.
Third last payment $= e \times 1.0\,p^2$.
First payment $= e \times 1.0\,p^{n-1}$.

In all, n payments, the sum of which forms an increasing geometric series of n terms, with a ratio of $1.0\,p$. For this, use formula:

$$\text{Sum} = \frac{\text{First term (Ratio}^n - 1)}{\text{Ratio} - 1}.$$

Substituting e for first term and $1.0\,p$ for ratio, gives:

$$\frac{e\,(1.0\,p^n - 1)}{1.0\,p - 1} = \frac{e\,(1.0\,p^n - 1)}{0.0\,p}$$

$$= \frac{e}{0.0\,p}\,(1.0\,p^n - 1). \quad . \quad \text{(Formula IV)}$$

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[*] Chapman, H. H., "Forest Valuation," John Wiley and Sons, Inc., N. Y., 1915, page 66.

Since $\frac{e}{0.0p}$ gives the capital value of e, it represents the sum which would earn e as interest annually at p per cent.

Let $E = \frac{e}{0.0p}$ = capital value of e.

Then cost of annual expenses $= E(1.0p^n - 1)$, or $E \times 1.0p^n - E$.

This last form emphasizes the fact that E is never expended, but, only the compound interest upon the value represented by E.

e. For present value of temporary annual rentals.

Each rental may be discounted to the present by using Formula I, but the same result is more easily obtained by discounting the final future value of the sum of these rentals to the present, using Formulæ II and IV for this purpose.

By Formula IV the future value of these temporary annual rentals $= \frac{e(1.0p^n - 1)}{0.0p}$ which may be discounted to the present by multiplying by $\frac{1}{1.0p^n}$ as shown in Formula II. Hence,

$$\frac{e(1.0p^n - 1)}{0.0p} \times \frac{1}{1.0p^n} = \frac{e(1.0p^n - 1)}{0.0p \times 1.0p^n}. \quad \text{(Formula V)}$$

The values for Formulæ IV and V are given in Columns III and IV, respectively, of the compound interest tables in the Appendix. (See pages 246 to 260.)

Additional formulæ of compound interest will be found in Chapter V of Chapman: "Forest Valuation" or in Chapter II of Roth: "Forest Valuation." *

117. Rate of Interest. — The rate of interest is especially important in long time investments — such as forestry — whose income is deferred. The interest rate is determined primarily by the use of money in loans. This rate is influenced by the following factors:

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* Roth, F., "Forest Valuation," Ann Arbor, Mich., 1916.

- *a.* Risk, or danger of loss of interest or principal.
- *b.* Cost of collection of interest.
- *c.* Duration of the investment.
- *d.* Rising prices.

In order to determine the rate of interest that should be charged for forest investments as compared with other forms of investment, the following factors should be taken into account:

- *a.* Since forest investments actually tie up funds for long periods, even where the enterprise as a whole may pay annual returns, comparison on basis of annual interest cannot be made.
- *b.* Investments for long periods as savings banks, and life insurance, pay 3 to 4 per cent, compound interest, up to approximately 20 years.
- *c.* Business investments which do not pay annual interest are not usually computed by investors on basis of compound interest, though they should be. Such investments are considered satisfactory if after periods of 20 years they return 4 per cent compound interest.
- *d.* The best short time investments in growing timber may pay 4 to 6 per cent compound.
- *e.* For investments over 50 years, no existing money or business investments can be compared. One must gauge the rate by comparison with *shorter* investments since the comparatively enormous increase of compound interest over simple interest, for high rates and long periods, causes conditions which are impossible of fulfilment. Forests will actually earn 2 to 3 per cent compound, for very long periods.

Writers differ on the rate of interest to adopt for forest investments. Roth * is a strong believer in an interest rate of not to exceed 3 per cent. Fairchild,† on the other hand, holds that

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* Loc. cit., pages 24–29, 55, and "Business Rate of Interest and Rate Made by the Forest," For. Quart., Vol. XIV, No. 2, pages 255–259.

† Fairchild, F. R., "Taxation of Timber Lands," in Report of National Conservation Commission, 1908, page 616 ff.

"these rates are too low, at least for American conditions. To mention only two reasons for this belief: In the first place, the risk of fire is so great that no insurance company will accept it. In the second place, forestry is peculiar in the long interval of time which must generally elapse before the investment begins to yield an income. It is a well-known psychological fact that such an income will be discounted at a higher rate of interest than those whose enjoyment is less remote.

"Without mentioning other reasons for a high rate, the writer is convinced that, as compared with ordinary investments, forest investments must be capitalized at a relatively high rate of interest. Five per cent is certainly not too high. It is very probably too low."

In European forestry, Pilz * has shown, conclusively, that the following rates of interest are earned on the capital invested.

	Per Cent
I. Government forest:	
Saw-timber over 100 years old, deciduous	1½
Saw-timber under 100 years old, deciduous	2
Saw-timber up to 100 years old, conifers	2
Coppice, pulp-wood, etc	2½
II. Large, corporately owned forest:	
Add one-quarter per cent to above rates.	
III. Small, corporately owned, and private forest:	
Deciduous saw-timber	2½
Coniferous saw-timber and deciduous coppice.	3

118. Calculation of Costs. — In order to determine the true economic relation of cost and expenses to income, cost accounts must be kept. In proprietary accounts the element of time is wholly neglected, and it is this inconsistency that the cost account eliminates. This is accomplished by the adoption of a rate of interest by which all expenditures are computed forward to the year when the income, for which the cost was incurred, is finally received.

The calculation of costs in forest production results in one side of the equation for securing an economic forecast in forestry.

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* Allgemeine Forst- und Jagd- Zeitung, January, 1914.

This economic forecast consists of balancing past cost with compound interest to date, against future income discounted to date as represented by the expectation value of assets. A comparison of past net outlay and future net income for any specific year, will show the exact economic status for that year.

Costs incurred in forest production are of three principal kinds and may be grouped as follows:

I. Investments or permanent outlay.
II. Initial expenditures.
III. Annual expenditures.

The various items with which most investments in forest production are concerned, fall within these groups as follows:

Group I:
  Land.
  Permanent improvements.
Group II:
  Standing timber.
  Reforestation expenses.
Groups III:
  Silviculture and protection.
  Taxes.*

Let S = cost of land.
C = initial costs of reforesting.
e = annual protection expenses.
n = number of years in period.

Using these letters, the following formulæ of compound interest are employed to calculate the costs of forest production.

Group I. Let land (S) serve as an example.

Total costs $= S\,(1.0p^n) - S$.

Group II. Let costs of re-forestation (C) serve here as an example.

Total costs $= C\ (1.0\ p^n)$.

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* Under the general property tax, this cost will be an annuity. Under some form of taxation whereby land and timber are taxed separately, the tax on land would be an annuity, while the tax on timber would, in all probability, be a yield tax into which no interest costs would enter.

Group III. Let e — the annual expense of protection — serve here.

Total costs $= \frac{e}{0.0\,p}(1.0\,p^n - 1)$ (see Formula IV, Article 116),

or

$$\frac{e}{0.0\,p} = E,$$

and

$$\text{Total costs} = E\,(1.0\,p^n - 1).$$

It will be unnecessary to go through the mathematics of working out by logarithms each value desired; results can be secured from Column III of the interest tables in the Appendix.*

Using the formulæ given above, the total costs would be equal to

$$S\,(1.0\,p^n) - S + C\,(1.0\,p^n) + E\,(1.0\,p^n - 1)$$

or

$$S + C + E\,(1.0\,p^n) - (S + E). \quad . \quad . \quad . \quad . \quad \text{(Formula VI)}$$

Where cost is incurred in a year a after the time at which the investment started, but previous to the year n, when the final returns are secured, this cost must be carried forward for $(n - a)$ years and the amount added to the total of other costs. In like manner, income received in a year a, must be carried forward for $(n - a)$ years and the amount added to the gross returns.

The following practical considerations enter into the cost of growing timber crops:

a. Comparison of cost of artificial crop production with native grown timber, and the prospects for the future. Advisability of plantations now must be judged by markets fifty years from date.

b. Cost of securing reproduction by leaving seed trees. Net cost depends on whether these survive; in which case it equals $C \times 1.0\,p^n - C_n$ where C = original value and C_n = final value of trees.

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* See Article 116, "Compound Interest Formulæ" and Appendix pages 246 to 260.

c. Cost of disposal of slash after logging.

It is a measure of initial fire protection expenses.

As such it should be calculated *per acre* and charged against the new crop.

In practice it is charged against the standing timber reducing the proceeds from the sale of stumpage.

d. Costs incurred in leaving a large percentage of the stand for a second cut.

1. Marking timber for removal.
2. Precautions to prevent injury to standing timber, *e.g.*, brush disposal.
3. Increased cost per M. feet of transportation charges.

These items are a charge against the second crop, on the basis of the stand or M. feet per acre at time of returning.

Total actual cost of leaving part of the stand for a second crop is the present value of timber left, plus total expenses incurred, including taxation and interest on land, or $(C + S + E)\ 1.0p^n - (S + E)$ when C = value of timber and initial costs.

119. Determination of Profits. — Knowing the total cost of the investment, this can be subtracted from the future stumpage value (see Article 121 for determination of stumpage values), and thus the profit determined. The following table[*] shows for a wide range of yields and stumpage prices, the net profit and corresponding compound interest rate on a number of different initial investments. This is the rate of interest actually earned, as explained under *c* in Article 116.

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[*] Sterrett, W. D. and Barrows, W. B., "Tables for Determining Profits in Forestry," For. Quart., Vol. XIII, No. 1, pages 12–14.

RATES OF INTEREST ON DIFFERENT INITIAL INVESTMENTS IN TIMBER GROWING CALCULATED FOR VARIOUS YIELDS, STUMPAGE VALUES, AGES, AND COSTS OF LAND AND ESTABLISHMENT.

Yield per Acre — Board Feet; and Stumpage Values per M. Feet.

	Initial investment.				5 M.				10 M.				20 M.				30 M.				40 M.				50 M.			
					$5	$10	$15	$20	$5	$10	$15	$20	$5	$10	$15	$20	$5	$10	$15	$20	$5	$10	$15	$20	$5	$10	$15	$20
Age, years.	Land.	Establishment.	Total.	Expenses.*	Profit, per cent.†				Profit, per cent.				Profit, per cent.				Profit, per cent.				Profit, per cent.				Profit, per cent.			
30	5	0	5	7.90	5.1	7.8	9.3	10.4	7.8	10.4	11.9	13.0	10.4	13.0	14.6	15.7	11.9	14.6	16.2	17.3	....	....	....	....	....	....	....	....
	5	5	10	7.90	....	5.3	6.8	7.9	5.3	7.9	9.4	10.4	7.9	10.4	12.0	13.1	9.4	12.0	13.5	14.6	....	....	....	....	....	....	....	....
	10	5	15	11.86	....	4.0	5.4	6.5	4.0	6.5	7.9	9.0	6.5	9.0	10.5	11.5	7.9	10.5	12.0	13.1	....	....	....	....	....	....	....	....
	10	10	20	11.86	....	....	4.4	5.4	....	5.4	6.9	7.9	5.4	7.9	9.4	10.5	6.9	9.4	10.9	12.0	....	....	....	....	....	....	....	....
	15	10	25	15.81	....	....	3.7	4.7	....	4.7	6.1	7.2	4.7	7.2	8.6	9.7	6.1	8.6	10.1	11.2	....	....	....	....	....	....	....	....
	15	15	30	15.81	....	....	3.1	4.1	....	4.1	5.5	6.5	4.1	6.5	8.0	9.0	5.5	8.0	9.4	10.5	....	....	....	....	....	....	....	....
40	5	0	5	15.48	....	5.3	6.6	7.5	5.3	7.5	8.7	9.5	7.5	9.5	10.7	11.5	8.7	10.7	11.8	12.7	9.5	11.5	12.7	13.5	....	....	....	....
	5	5	10	15.48	....	3.5	4.8	5.6	3.5	5.6	6.8	7.6	5.6	7.6	8.8	9.6	6.8	8.8	9.9	10.7	7.6	9.6	10.7	11.5	....	....	....	....
	10	5	15	23.22	....	....	3.6	4.5	....	4.5	5.7	6.5	4.5	6.5	7.7	8.5	5.7	7.7	8.8	9.6	6.5	8.5	9.6	10.4	....	....	....	....
	10	10	20	23.22	....	....	....	3.7	....	3.7	4.9	5.7	3.7	5.7	6.9	7.7	4.9	6.9	8.0	8.8	5.7	7.7	8.8	9.6	....	....	....	....
	15	10	25	30.95	....	....	...	3.1	....	3.1	4.3	5.1	3.1	5.1	6.3	7.1	4.3	6.3	7.4	8.2	5.1	7.1	8.2	9.0	....	....	....	....
	15	15	30	30.95	....	....	....	....	....	....	3.8	4.6	....	4.6	5.8	6.6	3.8	5.8	6.9	7.7	4.6	6.6	7.7	8.5	....	....	....	....
50	5	0	5	29.04	....	3.3	4.8	5.6	3.3	5.6	6.6	7.4	5.6	7.4	8.4	9.0	6.6	8.4	9.3	10.0	7.4	9.0	10.0	10.6	7.9	9.5	10.5	11.1
	5	5	10	29.04	....	....	3.3	4.1	....	4.1	5.2	5.9	4.1	5.9	6.9	7.5	5.2	6.9	7.8	8.4	5.9	7.5	8.4	9.1	6.4	8.0	8.9	9.6
	10	5	15	43.55	....	....	....	3.0	....	3.0	4.2	4.9	3.0	4.9	5.9	6.6	4.2	5.9	6.9	7.5	4.9	6.6	7.5	8.2	5.5	7.1	8.0	8.7
	10	10	20	43.55	....	....	....	....	....	....	3.6	4.3	....	4.3	5.3	6.0	3.6	5.3	6.3	6.9	4.3	6.0	6.9	7.6	4.9	6.5	7.4	8.1
	15	10	25	58.07	....	....	....	....	....	....	....	3.7	....	3.7	4.8	5.5	....	4.8	5.7	6.4	3.7	5.5	6.4	7.1	4.3	6.0	6.9	7.6
	15	15	30	58.07	....	....	....	....	....	....	....	3.4	....	3.4	4.4	5.1	....	4.4	5.4	6.0	3.4	5.1	6.0	6.7	3.9	5.6	6.5	7.2
60	5	0	5	53.32	....	....	....	4.0	....	4.0	5.1	5.9	4.0	5.9	6.7	7.3	5.1	6.7	7.6	8.2	5.9	7.3	8.2	8.7	6.4	7.8	8.6	9.1
	5	5	10	53.32	....	....	....	....	....	....	3.9	4.6	....	4.6	5.5	6.1	3.9	5.5	6.3	6.9	4.6	6.1	6.9	7.5	5.1	6.6	7.3	7.9
	10	5	15	79.97	....	....	....	....	....	....	....	3.7	....	3.7	4.7	5.3	....	4.7	5.5	6.1	3.7	5.3	6.1	6.7	4.2	5.8	6.6	7.1
	10	10	20	79.97	....	....	....	....	....	....	....	3.2	....	3.2	4.2	4.8	....	4.2	5.0	5.6	3.2	4.8	5.6	6.2	3.7	5.2	6.1	6.6
	15	10	25	106.63	....	....	....	....	....	....	....	....	....	....	3.6	4.3	....	3.6	4.5	5.1	....	4.3	5.1	5.7	3.1	4.8	5.6	6.2
	15	15	30	106.63	....	....	....	....	....	....	....	....	....	....	3.3	4.0	....	3.3	4.2	4.8	....	4.0	4.8	5.4	....	4.4	5.3	5.8
70	5	0	5	96.80	....	....	....	....	....	....	3.6	4.5	....	4.5	5.5	6.1	3.6	5.5	6.3	6.8	4.5	6.1	6.8	7.3	5.1	6.5	7.2	7.7
	5	5	10	96.80	....	....	....	....	....	....	....	3.5	....	3.5	4.4	5.0	....	4.4	5.2	5.8	3.5	5.0	5.8	6.3	4.0	5.4	6.2	6.7
	10	5	15	145.20	....	....	....	....	....	....	....	....	....	....	3.5	4.2	....	3.5	4.4	5.0	....	4.2	5.0	5.6	....	4.7	5.4	6.0
	10	10	20	145.20	....	....	....	....	....	....	....	....	....	....	3.1	3.8	....	3.1	4.0	4.6	....	3.8	4.6	5.1	....	4.2	5.0	5.5
	15	10	25	193.59	....	....	....	....	....	....	....	....	....	....	....	3.2	....	....	3.5	4.1	....	3.2	4.1	4.7	....	3.7	4.6	5.1
	15	15	30	193.59	....	....	....	....	....	....	....	....	....	....	....	....	....	....	3.2	3.8	....	....	3.8	4.4	....	3.4	4.3	4.8

* Five cents per acre annually for administration (including fire protection) and one cent on the dollar (full valuation) annually for taxes, with compound interest at 6 per cent.

† Calculated by the formula $p = 100\left(\sqrt[n]{\frac{S+L-A}{L+F}} - 1\right)$ where p = compound interest rate, n = number of years or rotation, S = stumpage value at n years, L = cost of land, F = cost of formation, and A = cost of administration and taxes in n years at 6 per cent compound interest. The author's symbols have been retained although they differ from the ones used in this Chapter.

This table may be practically applied as follows:

McCarthy's yield table for white pine near Ithaca, N. Y. (see Article 79, Fig. 23), shows about 20 M. feet, b. m., per acre at 60 years. If the land is worth $10.00 an acre, planting costs $10.00 an acre, and annual administration expenses and taxes are 5 cents per acre per annum for administration and fire protection and 1 cent on the dollar annually for taxes with compound interest at 6 per cent, what rate of interest may be expected if the stumpage value in 60 years from now is $10.00 per M.?

Using the table, the answer = 3.2 per cent.

If the stumpage value were $15.00 the answer would be = 4.3 per cent. With money at 5 per cent there would here be no enterpriser's profit. (The enterpriser is the one who undertakes — the "entrepreneur.")

The gaps in the table may be filled by interpolation. Thus, other factors being equal, the interest rate for a stand in which the initial investment is $12.00 per acre, would be between the rates for $10.00 and $15.00 investments. Similarly, the interest rate for a stand containing 25 M. board feet per acre would be intermediate between one of 20 M. and one of 30 M. per acre. Thus, in the first example, the yield table (Article 79, Fig. 23), shows 20,920 board feet per acre at 60 years; this is practically 21 M. The interest rate, as shown, is 3.2 per cent for 20 M. per acre; it is 4.2 per cent for 30 M. per acre, for 21 M. it is one-tenth of the difference, or 3.3 per cent.

The interest rates earned by white pine stands on medium quality sites, using the values given in table 6 of U. S. Dept. of Agriculture Bul. 13, "White Pine under Forest Management," are as follows:

Rotation, years.	Volume per acre, feet, board measure.	Stumpage value per M. feet, board measure.	
		$10 Interest per cent earned.	$15 Interest per cent earned.
30	9,600	5.4	6.9
40	23,500	5.9	7.1
50	36,600	5.8	5.7
60	46,900	5.1	6.0
70	56,100	4.4	5.2

With money at 5 per cent there would be an enterpriser's profit in all but one instance; at 6 per cent in only two instances.

From the data in tables 15, 16 and 17 of Bul. 13, it appears that, under optimum conditions, the net profit, per acre per annum, from growing white pine is as follows:

Money at 4 per cent compound......	$5.20 net profit per acre per year.
Money at 5 per cent compound......	$4.42 net profit per acre per year.
Money at 6 per cent compound......	$4.22 net profit per acre per year.

The maximum income, per acre per annum, from the State forests of Germany has been as follows:*

Württemberg.		Saxony.		Bavaria.		Prussia.		Average of net returns.
Gross.	Net.	Gross.	Net.	Gross.	Net.	Gross.	Net.	
$ 10.90	$ 7.47	$ 9.60	$ 6.17	$ 6.30	$ 3.30	$ 5.19	$ 2.98	$ 4.98*

* By using the values for several years and by taking into account the acreage of forest in each country, the average net returns per acre per annum are as follows:

Württemberg............	490,000 acres	$6.64............	1905 to 1909 incl.
Saxony..................	431,000 acres........	5.55............	1905 to 1911 incl.
Bavaria..................	2,330,000 acres........	2.71............	1905 to 1909 incl.
Prussia..................	6,796,000 acres........	2.33............	1905 to 1911 incl.
Proportioned average for	10,047,000 acres.......	$2.7617 =	Net annual revenue per acre.

120. Financial Advantages of Sustained Annual Yield. — The advantages of a sustained annual yield (see Article 77) over a single yield once in a long period of years (called "intermittent management") are well illustrated by the following comparison of the two adapted from Roth: "Forest Valuation." †

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* Adapted from Roth, "Forest Valuation," page 138.

† "Forest Valuation," F. Roth, Ann Arbor, Mich., 1916, page 83.

COMPARISON OF YEARLY AND INTERMITTENT WORKING

Premises. — Area 1000 acres; rotation, 80 years; interest rate, 3 per cent; value of timber at rotation age, $400 per acre; land cost $10 per acre; m.a.i. = 1 cord per acre; value per cord, $4.00; cost of planting, $10.00 per acre; current expenses, $1.00 per acre. Thinnings omitted.

	Property with yearly cut and yearly income.	Property with a cut and income every 80 years.
1. Growing stock at beginning	40,000 cords	None
2. Growth of merchantable material during the 80 years	80,000 cords	80,000 cords
3. Growing stock at end of 80 years	40,000 cords	80,000 cords
4. Value of property at beginning	$10,000 for land and about $60,000 for growing stock.	$10,000 for land nothing for growing stock; might include value of plantation.
5. Income during the 80 years	$320,000 plus interest.	None, thinnings not considered.
6. Income at 80, *i.e.*, in last year	$4000	$320,000
7. Condition at end of first 20 years	Has earned: Per year: Income: $4000 Expenses: Rent $335 Tax and care $1000 Planting $125 Total expense $1460 Net income per year $2540 Net income for 20 years $2540 \frac{(1.03^{20}-1)}{1.03-1}$ or about $68,250	In debt: Expenses per year: Rent $335 Tax and care $1000 Total $1335 For 20 years expenses $1335 \frac{(1.03^{20}-1)}{1.03-1}$ or $35,871 For planting $10,000 Plus interest or 10,000 (1.03^{20}) = 18,000 Total expenses for 20 years: $53,871

121. Stumpage Values. — Chapman * defines stumpage value as "the sale value of merchantable standing timber — its value on the stump previous to felling and removal." This value may be determined:

I. As lump sum: this may be per acre or for entire tract.
II. Per unit of product:
  (*a*) Based on actual sales in the vicinity.
  (*b*) Based on appraised value:
    (1) According to per cents of grades and grade prices.
    (2) According to mill run selling price.

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* "Forest Valuation," Chap. XI.

Of these the last named is the one most commonly used. The appraised value is more reliable than a figure based on precedent or a lump sum.

The appraisal of stumpage value is based on costs of logging and milling (O) on selling price (S), and on a fair profit (p) in the investment. These three factors must be determined for every prospective operation.

The main items of costs entering into lumbering operations are as follows, per M. feet, board measure:

d = investment charge (sinking fund or depreciation).
i = interest on investment.
c = operating costs — stump to f.o.b. cars.*
m = maintenance of plant and equipment unless included in c.
v = office charges, taxes, insurance (overhead expenses).
r = additional cost of logging under forest management (see Article 118).
w = wrecking value of d at end of operation — to be deducted from d.

The item d should, as a rule, include all of the initial investment in mills, yards, railroads, tramways, livestock, logging equipment, etc., necessary to put the finished product on the market in the logical manner indicated by local conditions, minus the estimated cash value of the plant and equipment at the end of the operation. The item may generally be handled in the following manner: Suppose the purchaser of 10,000,000 feet of timber under a five-year contract is required to invest $20,000 in a plant and equipment. Presuming that the average annual cut will be 2,000,000 feet, the investment charge amounts to $4000 per annum (if it is considered that the plant and equipment will have no actual sale value at the end of the operation), and this sum prorated over the 2,000,000 feet handled annually makes the item d equivalent to $2.00 per M. If, however, it is estimated that the plant and equipment will have an actual sale value of $10,000 at the end of the operation, the item *d* is reduced to $1.00 per M.

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* For outline of logging and milling costs see: Recknagel, A. B., "Theory and Practice of Working Plans," 2nd. edit., John Wiley and Sons, Inc,. N. Y., 1917, pages 33-36

In computing the item *i*, it should be considered that half of the full initial investment has been retired at the expiration of one-half of the contract period. Therefore, it is permissible to reverse this assumption and, for the sake of simplicity, to allow interest on the full investment for one-half of the contract period, and the item *i* should be so computed at six per cent simple interest. In the above assumed case as an example, simple interest on $20,000 at six per cent would be figured for 2½ years, amounting to a total of $3000. This amount prorated over the total cut of 10,000,000 feet makes the item *i* equivalent to $0.30 per M. It should be noted that this item is not decreased if a wrecking value is calculated, since the $20,000 is invested for the full period of the operation and interest should be allowed regardless of any amounts which may be returned through the sale value of the equipment at the end of the operation.

The item *m* should not be confused with the investment or depreciation charge. It covers the amount expended solely for the purpose of keeping the plant and equipment in working efficiency during the operation. That is, it represents the cost of necessary repairs and replacements only.

Under item *c* should be included wagon roads, since such roads will be an investment for which there are no appreciable assets at the end of the operation. Such roads will usually have to be abandoned or will become county roads at a future date.

In charging against the item *r*,[*] consideration should be given to such factors as brush disposal, cutting of snags and dead trees, utilization of small or inferior material which can be handled at little or no profit, and the amount of stumpage handled per acre. This latter point will be governed largely by the recommended system of marking, *i.e.*, the percentage of the merchantable stand marked for removal. It should be borne in mind that, other conditions being equal, the cost of logging is about proportional to the amount of timber handled per acre.

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[*] See Chapman, "Forest Valuation," Article 107, page 81.

The item w should be handled with great care. It should be limited in all cases to the estimated cash value of the plant and equipment at the end of an operation.

The total cost, *exclusive of stumpage*, should be summarized in the above manner and the average mill run selling price f.o.b. cars, or other point of sale, should be determined as accurately as is feasible. The operating costs and average mill run selling price, together with the per cent of operating profit to be allowed the purchaser, having been determined, the true value of the stumpage may be found by the three following formulæ in which

x = unknown stumpage value.
s = average selling price.
o = operating costs = $(d - w) + i + c + m + v + r$.
p = per cent of operating profit.

Formula A, known as the forester's formula, was first promulgated by the U. S. Forest Service in January, 1912 and reads:

$$x = s - o - p(o) - p(x),$$

or, in abbreviated form (by algebraic reduction):

$$x = \frac{s}{1 + p} - o.$$

This formula allows a percentage of profit on the stumpage price as being one of the operating costs and "was formerly advocated by the Forest Service for use in small sales where but little capital is invested but has been set aside" * in favor of formula B.

Formula B reads:

$$x = s - o - p(o).$$

"The computation of profits as a per cent of operating costs, if based on the results of individual operations, would place a premium on extravagance. But when gauged by average costs of well-conducted operations of similar size, and applied in determining appraisals in advance of cutting, no such objection can be urged." *

Formula C reads:

$$x = q(s - o),$$

* Chapman, "Forest Valuation," page 183.

in which q is the per cent of net income taken for stumpage value — it shares the profit between the owner of the stumpage and the operator. "Such a plan requires complete confidence in the integrity of the operator or a right to inspect his books, and is not generally practiced, though one of the most equitable of methods." [*]

In using formulæ A and B it is necessary to take into account the over-run of mill scale over log scale. "All log scales in extensive commercial use give less than the contents ordinarily sawed from logs, and this discrepancy increases as utilization becomes closer. The excess of manufactured lumber over the contents measured by the log scale is termed over-run." [†]

The stumpage value per thousand feet of sawed lumber multiplied by 1 + the percentage of over-run will give the correct stumpage value per thousand feet, log scale.

Examples of Stumpage Determination. — In a given operation in New York State [‡] the operating costs (o) were as follows:

Cutting	$1.50 per M. feet, b. m.
Skidding	1.75 per M. feet, b. m.
Sawing	3.50 per M. feet, b. m.
Piling	1.00 per M. feet, b. m.
Hauling	5.00 per M. feet, b. m.
Total	$12.75 per M. feet, b. m.

The average mill run selling price (s) was $25.00 per M., and the per cent of operating profit (p) was 25 per cent. The over-run of mill scale over log scale was 15 per cent, that is, each thousand feet log scale produced 1150 board feet of lumber.

By using formulæ A and B, the results are per M. feet, b. m., as follows:

Item.	Without over-run.		With over-run.	
	Formula *A*.	Formula *B*.	Formula *A*.	Formula *B*.
	$	$	$	$
Stumpage value	7.25	9.06	8.34	10.42
Profit per M	5.00	3.19	3.91	1.83

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[*] Chapman, "Forest Valuation," page 184.

[†] Chapman, "Forest Valuation," page 187. See above Chapter III, Article 12.

[‡] Bul. 9, N. Y. State Conservation Commission, 1st. edit., pages 95–98, 2d. edit., page 57.

By using formula C and assuming that q, the per cent of net income taken for stumpage value, is 50 per cent the result is, per M. feet, b. m , as follows:

$$x = q\,(s - o) = 0.50\,(25.00 - 12.75) = 0.50\,(12.25)$$
$$= \$6.125 = \text{stumpage value.}$$

Stumpage values in Germany and other European countries are as follows:

Good Scotch pine, Germany and France, \$12–\$24 per M.[*] Dr. House [†] gives for Scotch pine in Eberstadt near Darmstadt a stumpage price of \$60 per M. feet, b. m.

In general, stumpage prices in Europe for timber of moderate accessibility and of such species as Scotch pine, Norway spruce, etc., vary from \$15 to \$35 per M. The spruce and fir in the Black Forest bring an average stumpage price of \$24 per M.

For stumpage values in America, Roth [‡] says: "Stumpage prices today vary not only for species but vary with market, railway facilities, habit of the people of the district, etc. Average figures for stumpage have little value, they vary chiefly between \$3 and \$7, go as high as \$20 and as low as \$1, and generally make from 10 to 30 per cent of the value of the lumber at the mill."

NOTE. — For further details regarding Stumpage Values and Methods of Stumpage Appraisal, see: Chapman, "Forest Valuation," Chapters XI and XIV; Roth, "Forest Valuation," Chapter VI; and U. S. Department of Agriculture, Forest Service, "Manual of Stumpage Appraisals," Nov., 1914.

122. Appraisal of Damages. — Chapman [§] lists the following principles underlying the appraisal of damages to forest property:

(*a*) Damages are payable in money — compensation, not restoration.

(*b*) Difference in value before and after damages is the basis.

(*c*) Sale value is an important index but is not a final standard of value.

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[*] U. S. Dept. of Agric., Bul. 139, "Norway Pine in the Lake States."

[†] Report of the New York State Botanist, 1913, page 4.

[‡] Roth, "Forest Valuation," page 91.

[§] Chapman, "Forest Valuation," Chapter IX.

(*d*) Value set by owner must have commercial, rather than personal, basis.*

(*e*) Prospective income, if reasonably certain, is accepted, but not when based on speculative or contingent factors.

(*f*) Cost of restoration is the basis if less than the present value.

(*g*) Average costs or income, rather than individual or exceptional figures, are accepted.

(*h*) Damages must be proved with reasonable certainty.

Based on these principles, the U. S. Forest Service, on February 6, 1914, issued "Standard Instructions for the Determination of Fire Damages." These instructions make no attempt, for the present, to estimate the loss in soil productivity due to the destruction of humus and litter and to changes in the physical characteristics of the soil, or to the increased danger from insects and disease, although it is recognized that these may frequently represent real and important damages. Soil rental (see Article 94) is also to be omitted from calculations of expectation and replacement values, since under present conditions it is so difficult to determine, is to a large extent offset by other factors, and unnecessarily complicates the problem.

The government's detailed instructions for calculating fire damages are given below:

I. TIMBER

Definition of mature timber.

1. *Mature Timber.* — This includes all timber which is of sufficient size to be ready for cutting according to the general lumbering practice of the region. Burns in mature timber will fall into three general classes:

Entire stand rendered unmerchantable.

(*a*) Where the entire stand is killed and rendered unmerchantable by the fire. In this case the damage will be assessed at the full stumpage value of the timber, both live and dead, immediately before the fire, determined according to the usual method of appraising stumpage for timber sales. Other products than lumber, such as poles, ties, mining props, fencing, fuel, etc., for which there is a market, should be included in determining

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* *Ibid.*, p. 121: "Æsthetic values, or the value of 'legitimate gratification,' must be recognized whenever based on elements generally accepted by the public at large. Sentimental value peculiar to the owner cannot be admitted." And on page 139 he says: "the æsthetic values destroyed may frequently be gauged roughly by the loss in sale value of the entire property."

Inaccessible stands.

the value of the stand. When the stand destroyed is so inaccessible as to be at present unmerchantable, its stumpage value will be taken as the minimum rate for the Forest.

Stand killed but in part merchantable.

(*b*) Where the entire stand is killed, or so damaged that it will die in a few years as a direct result of the fire, but where some of the timber is still merchantable. In this case the timber should be advertised for sale with or without naming a minimum price, depending on the circumstances in each case. If sold, the damage would be the difference between the appraised stumpage value of the timber before the fire and the selling price. If not sold, the damage should be taken as the full appraised value before the fire.

Stand only partly killed.

(*c*) Where part of the stand is killed and part left undamaged, either in the form of single trees or solid blocks. In this case the damage would be the difference between the appraised stumpage value of the entire stand before the fire and the appraised value of the remaining merchantable stand after the fire, or its sale value if an immediate sale is practicable. The stumpage value of the undamaged timber would ordinarily be less after the fire than before, as a result of the increased cost of logging due to the destruction of part of the stand.

Definition of immature timber.

2. *Immature Timber.* — This includes all timber not yet merchantable, that is, timber which is still too small to be ready for cutting according to the general lumbering practice of the region. Stands of immature timber will fall into two general classes:

Stands approaching merchantability.

(*a*) Stands which are approaching merchantability. The lower age-limit for this class is the age at which the trees have obviously passed the stage of being mere "reproduction." This will ordinarily be at from one-third to one-half the length of the rotation, depending upon the species and market conditions. The upper age-limit is the age at which the trees are obviously ready for cutting according to the general lumbering practice of the region.

Expectation value formula.

The damage to stands of this character will be taken as their expectation value. This is merely their estimated value at the end of the rotation, reduced by the cost of protection during the intervening period, and discounted to the present at compound interest. It may be determined by the formula

$$G = \frac{Y - \frac{e}{.0p} \times (1.0p^{n-m} - 1),}{1.0p^{n-m}}$$

where

G = expectation value of the young stand.

Stumpage value.

Y = stumpage value of the stand at the end of the rotation, based on present stumpage prices. The yield per acre at the end of the rotation should be estimated as accurately as possible

Yield tables. by means of empirical or normal yield tables. Empirical yield tables, giving the average cut at different ages for the region in general, will ordinarily be most satisfactory, particularly in irregular stands. Where normal yield tables are available, however, they may often be used to advantage, particularly in regular, well-stocked stands, making due allowance of course for the normality of the particular stand in question.

Annual expenses. e = annual expenses for fire protection. These should be as nearly as possible the average amount actually spent by the Forest Service for protection in the same general region, and will necessarily vary according to the topography and character of the stand. $\frac{e}{.op}$ is the capitalized value of the annual expenses, and is sometimes represented by the single symbol E.

Rate of interest. $.op$ = rate of interest. This will be taken uniformly as 3 per cent.

Length of rotation. n = length of rotation. This will vary according to the species, and should be the rotation which the Service actually plans to use for the species and locality under consideration.

Age of stand. m = present age of stand.

Stands only partially destroyed. Where only part of the stand has been destroyed, the amount of the damage is the difference between the expectation value of the stand before and after the fire. This may be determined by the formula

$$\text{damage} = \frac{Y - Y'}{1.0\,p^{n-m}},$$

where

Y' = stumpage value at the end of the rotation of that part of the stand remaining after the fire.

Practical examples. A 50-year-old fully-stocked stand of Douglas fir is destroyed by fire. Yield tables show that such a stand will yield 80 thousand board feet per acre in 100 years worth \$1.50 per thousand at present stumpage prices. The cost of fire protection is 3 cents per acre per year. The expectation value of the stand per acre, and consequently the amount of the damage suffered is therefore:

$$G = \frac{Y - \frac{e}{0.0\,p}(1.0p^{n-m} - 1)}{1.0\,p^{n-m}}$$

$$= \frac{80 \times 1.50 - \frac{0.03}{0.03}(1.03^{100-50} - 1)}{1.03^{100-50}}$$

$$= \frac{120 - (4.3839 - 1)}{4.3839}$$

$$= \frac{116.6161}{4.3839} = \$26.60.$$

If the stand were only partly destroyed, so as to reduce the yield at the end of the 100-year rotation to 40 thousand board feet, the damage per acre would then be:

$$\begin{aligned}\text{Damage} &= \frac{Y - Y'}{1.0p^{n-m}}\\ &= \frac{80 \times 1.50 - 40 \times 1.50}{1.03^{100-50}}\\ &= \frac{120 - 60}{4.3839}\\ &= \$13.68.\end{aligned}$$

Very young stands. (*b*) Stands which would generally be classed as "reproduction," and which obviously cannot be considered merchantable for some time to come. This will ordinarily include stands with ages up to one-third or one-half the length of the rotation.

Replacement value formula. The damage to stands of this character will be taken as the cost of replacement. This is merely the cost of planting or seeding the area plus the cost of fire protection, both items being calculated at compound interest for the number of years necessary to replace the stand destroyed. It may be determined by the formula:

$$R = C \times 1.0p^{m} + \frac{e}{0.0p}(1.0p^{m} - 1),$$

where

R = cost of replacement of stand.

Cost of stocking. C = cost of planting or seeding. That method of reforestation should be adopted which gives the most assurance of success under the given conditions of species, soil, climate, etc. Reasonable figures for cost should be used based on previous experience by the Service in similar situations.

Sufficient stock should be planted or sufficient seed sown to establish a stand which at the end of the rotation will produce as nearly as possible the same yield as would have been produced by that destroyed.

Rate of interest. $0.0p$ = rate of interest. This should be taken uniformly as 3 per cent.

m = number of years necessary to replace the stand. Ordinarily this will be the same as the age of the stand destroyed. Where, however, growth has been abnormally slow, as a result of overstocking or suppression, interest charges should be calculated only for the number of years which would normally be necessary to produce a stand of the size of that destroyed.

Annual expenses. e = annual expenses for fire protection. These should be as nearly as possible the average amount actually spent by the Service for protection in the same general region, and will necessarily vary according to the topography and character of the stand. $\frac{e}{0.0p}$ is the capitalized value of the annual expenses, and is sometimes represented by the single symbol E.

Where natural reproduction may be depended on. In burns where reproduction in sufficient quantities is already coming in naturally after a fire, or where it is certain that it will come in naturally within a reasonable time, no charge should be made for planting or seeding. In other words, C in the formula equals 0; and the cost of replacement is simply the cost of protection, at compound interest, for the number of years necessary to replace the stand destroyed. Where natural reproduction may be counted upon to come in slowly but surely after a fire, as with western yellow pine, this period may be considerably longer than the age of the stand destroyed, in order to allow a reasonable time for the reproduction to become established. In all cases where it is doubtful as to whether natural reproduction can be depended on, the cost of planting or seeding should be included.

Practical examples. A 10-year-old stand of Douglas fir is destroyed by fire. Natural reproduction is out of the question, but a similar stand can be replaced in ten years by planting at a cost of $6 per acre. The cost of fire protection is 3 cents per acre per year. The cost of replacement per acre, and consequently the amount of the damage suffered, is therefore:

$$\begin{aligned} R &= C \times 1.0p^m + \frac{e}{0.0p}(1.0p^m - 1) \\ &= 6 \times 1.03^{10} + \frac{0.03}{0.03}(1.03^{10} - 1) \\ &= 6 \times 1.3439 + (1.3439 - 1) \\ &= \$8.41. \end{aligned}$$

A 10-year-old stand of lodgepole pine is destroyed by fire. Natural reproduction takes place immediately and can be counted on to produce in ten years a stand as good as that destroyed. The cost of fire protection meanwhile is 3 cents per acre per year. The cost of replacement per acre, and consequently the amount of the damage suffered, is therefore:

$$\begin{aligned} R &= C \times 1.0p^m + \frac{e}{0.0p}(1.0p^m - 1) \\ &= 0 \times 1.03^{10} + \frac{0.03}{0.03}(1.03^{10} - 1) \\ &= 0 + (1.3439 - 1) \\ &= \$0.34. \end{aligned}$$

A 10-year-old stand of western yellow pine is destroyed by fire. Natural reproduction can be depended on to take place, but owing to the slowness with which the young growth comes in, 30 years will be required to replace a stand similar to that destroyed. The cost of fire protection is 3 cents per acre per year. The cost of replacement, and consequently the amount of the damage suffered, is therefore:

$$
\begin{aligned}
R &= C \times 1.0p^m + \frac{e}{0.0p}(1.0p^m - 1) \\
&= 0 \times 1.03^{30} + \frac{0.03}{0.03}(1.03^{30} - 1) \\
&= 0 + (2.4273 - 1) \\
&= \$1.43.
\end{aligned}
$$

Reasons for using both expectation value and cost of replacement value.

The use of both expectation value and cost of replacement value in the case of immature timber is necessitated by the fact that present stumpage prices bear no relation to the cost of timber production. Expectation value is the fairest to use with stands approaching merchantability since it can be determined with considerable accuracy and gives reasonable results, while cost of replacement value for such stands appears unreasonably high because of the present low stumpage prices. For very young stands, on the other hand, expectation value cannot be determined accurately because of the difficulty of predicting future yields so far in advance; furthermore, it is unreasonably low since it must be based on present stumpage prices, while as a matter of fact it is almost certain that stumpage prices will be considerably higher by the time the timber is mature. For such stands, therefore, cost of replacement value is preferable because it can be more accurately determined and gives more reasonable results. As stumpage prices approach the cost of growing the timber, expectation value and cost of replacement value also approach each other until they are the same for any given age when the stumpage price is exactly equal to the net cost of production.

Mature and immature timber on same area.

3. *Mature and Immature Timber on the Same Area.* — Stands of this character fall into two general classes:

Two-storied forests.

(*a*) Where the immature timber occurs in approximately even-aged stands as an understory beneath the mature timber. In this case the value of the mature and immature timber should be computed separately as provided for under 1 and 2, and the sum of these values taken as the damage to the stand. This is on the assumption that the reproduction already present would actually be used to re-stock the ground in case of a timber sale. If this is not true, that portion of the immature timber which would not be made use of after a timber sale should be disregarded in the calculation. In determining the value of the immature timber it should be borne in mind that unless the entire stand is destroyed, natural reproduction can usually be depended on to take place from seed trees left after the fire.

Selection forests.

(*b*) Where the mature and immature timber occurs irregularly over the area in the form of a selection forest. In this case the value of the mature timber should be determined as already outlined. The value of the immature timber should be determined either (1) by ascertaining its average age and finding the expectation or replacement value of a stand of this age and degree of stocking; or, (2) by dividing the young growth into a small number of age-classes, and finding the expectation or replacement value of each of these. In determining the value of the younger age-classes in the immature timber it should be borne in mind that, unless the entire stand is destroyed, natural reproduction can usually be depended on to take place after the fire.

II. Forage

Acreage basis; private rates.

Damage to forage will be estimated on an acreage basis at the current rates paid for grazing privileges on private land of similar carrying capacity. Thus, if 500 acres of range are burned over so as to be useless for grazing purposes for a full season of six months, and private land of similar carrying capacity rents for $64 per section, or 10 cents per acre, for an equivalent season, the damage would be 500 × $0.10, or $50. If the carrying capacity of the National Forest Range is less than that of the private land, or if the grazing season is shorter, or if the damage is such as not to prevent the use of the range for a full season, a corresponding reduction would be necessary in the value of the forage destroyed.

Carrying capacity.

Injury lasting several years.

If it can be conclusively established that the severity of the injury is such as to prevent the use of the range for a certain number of years, the value of the forage should be calculated for each year in the same manner. Unless the number of years can be determined with reasonable certainty, however, the estimate of damage should include only the value of the forage actually destroyed.

III. Protection

Unmerchantable stands.

When a stand is destroyed which never would be merchantable but which still has a value for watershed protection, its value will be taken as the cost of replacing a stand sufficient to exert the same amount of protection, as determined by the formula

$$R = C \times 1.0p^m + \frac{e}{0.0p}(1.0p^m - 1).$$

For the present, however, the value of C will be taken uniformly as 0, on the assumption that in all such cases natural reproduction can be relied upon to re-stock the area.* The amount of the damage, will, therefore, be merely the cost of fire protection, at compound interest, for the number of years until the new stand can be considered to afford the same amount of protection as that destroyed. Wherever a considerable period will be necessary for the reproduction to become established, this fact should be taken into consideration in determining the value of *m* in the formula.

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* Chapman, "Forest Valuation," page 138, favors using "the cost of re-establishing the protective cover, either by natural or artificial means, and of protecting this area from fire until it reaches the same state of effectiveness as that which was removed."

Merchantable stands, brush, and grass covers. For the present the value of merchantable stands which also exert a protective influence will be calculated as previously provided for, and no attempt made to charge for loss in protection during the period in which a new stand is being established. Similarly, no charge will for the present be made for the protective value of brush or grass covers.

IV. IMPROVEMENTS

The value of all improvements destroyed, such as cabins, barns, fences, telephone lines, etc., should be included in estimates of fire damages. This value should be based wherever possible on the original cost of construction, and where this is impossible on the cost of replacement. In either case an allowance should be made for depreciation of the improvements, in order to determine their actual value at the time of destruction.

V. FIRE FIGHTING

Full damages should be collected from the trespasser for the cost of extinguishing the fire, including salaries and expenses of Forest officers, wages of temporary labor, supplies, tools, teams, and miscellaneous items.

These instructions, though intended specifically for fire damages, will apply with equal force in gauging other forms of damage to forest property. Further details regarding the appraisal of damages will be found in Chapman, "Forest Valuation," Chapter IX; Roth, "Forest Valuation," Chapter VII; and Fernow, "Considerations in Appraising Damage to Forest Property," Forestry Quarterly, Vol. III, pages 119–142.

In all cases, a thorough field examination and careful estimate of the extent of the damage is essential. It is advisable to have this work supervised by some one of experience who can later qualify in court as an expert.

CHAPTER XVI

FOREST ADMINISTRATION

123. Introduction. — Forest administration deals with the principles of business conduct and the methods employed in the administration of forest properties. It divides into two parts: I. *Whose* are the duties of forest administration? *I.e.*, organization of forest staff. II. *What* are the duties of forest administration? *I.e.*, business practice. Only the first of these is within the scope of this book.

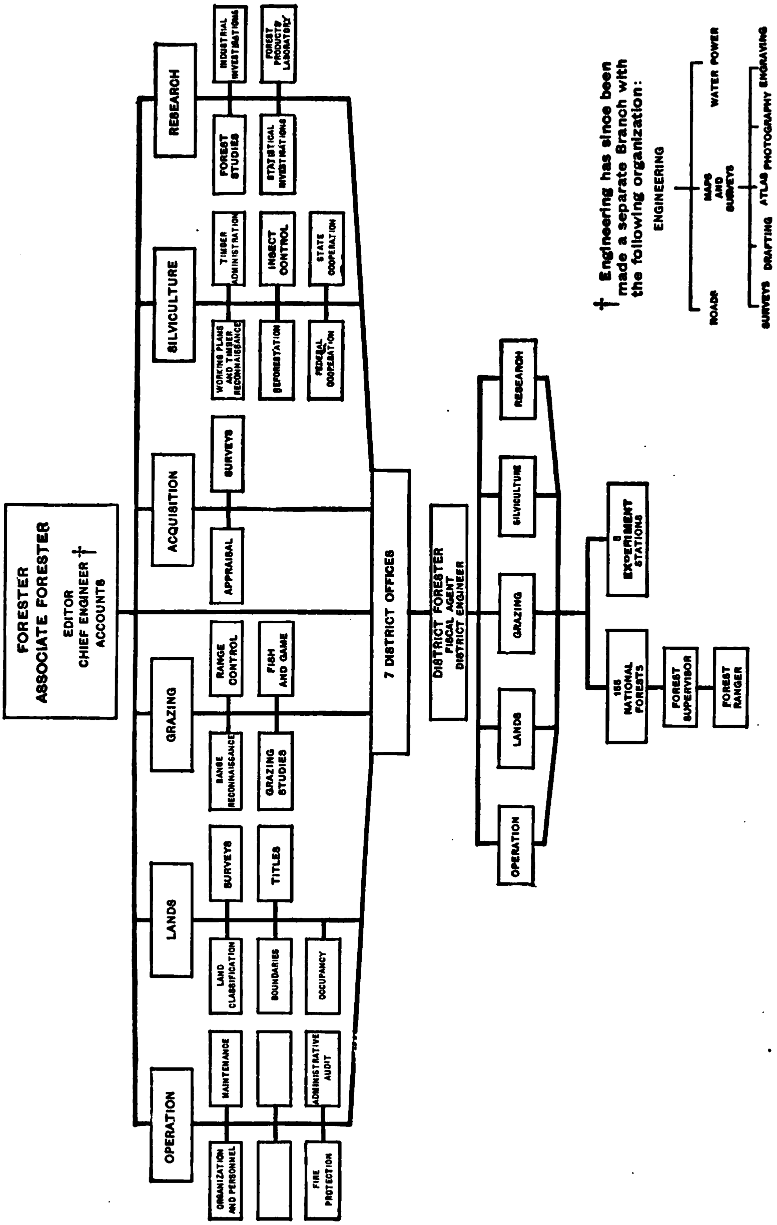
124. Organization of Forest Staff. — Here the task is to secure the best possible arrangement of human labor with respect to the work to be done in the forest. It varies according to character of owner (federal, state, communal, private), size of property, and intensity of management. With changing conditions, the ideal is constantly changing hence one must consider what, under a given set of conditions, is the best form of administration.

The subject of organization of forest staff may be divided into (*A*) functions and grades, (*B*) distribution according to area, and (*C*) personnel relations. These will be considered *seriatim*.

125. Functions and Grades. — The activities of a forest staff may be classified as: (1) directive, (2) inspective, (3) executive, (4) protective, and (5) special detail. These will be taken up in the order named; the organization of the U. S. Forest Service as shown in the accompanying chart will be used as an example.

126. Direction. — This may be handled in one of two ways. Either *Bureaucratically* by means of a Director or *Collegially* by means of a majority vote of the Committee or Commission directing the work. The former is of advantage where quick decisions are to be reached and matters pushed vigorously. In it, the responsibility is fixed upon the individual. The latter is of advantage where long and careful consideration must be

CHART SHOWING ORGANIZATION OF FOREST SERVICE, JUNE 1, 1915



† Engineering has since been made a separate Branch with the following organization:

FIG. 26.

given, *e.g.*, in mapping out a program of research work, in legal matters, in judging complaints against subordinates, etc.

The individual assignment of the directive work, *i.e.*, jurisdiction, may be according to *area* or according to *subject*. In the former, the official handles all cases in his particular area; in the latter all cases in his particular line of work. In practice, routine direction and inspection are according to area; law, fiscal matters, forest organization, according to subject. The former has the advantage of exact acquaintance with local conditions; the latter exact acquaintance with the field of activity. The larger the area and the more diverse the conditions encountered, the more is the area division to be recommended. However, specialized subjects are better handled by one man — *e.g.*, forest organization — for the whole District.

127. Inspection. — Is secured either by (1) the appointment of special inspectors or by (2) the district officers doing the inspecting themselves.

The District Inspector system is one of *Centralization*, *e.g.*, all handled from Washington, with long distance correspondence. The inspectors have no authority to correct things on the ground; they merely report — usually at great length.

The District Forester system is one of *Decentralization*. Its advantages are: (1) greater local knowledge on the part of those called to decide. (2) The results of inspection can be applied directly by the inspector, himself and *watched* by him. (3) Diminished correspondence and "paper work." The only disadvantages are that personal prejudice may enter into decisions and that the inspecting officer may not be quite so capable. The District Forester system is, with us, still according to *subject*. Each Assistant District Forester covers his subject for the entire area of the District. This is inevitable with present specialization — *i.e.*, the Assistant District Forester in charge of Grazing is scarcely in a position to decide Timber Sale questions and *vice versa*. However, an area assignment is the ideal towards which to strive. It has been attained abroad, where each Assistant District Forester is directly responsible for a group of forests and must visit them at least twice a year.

128. Execution. — This is the most important part of the whole administrative organization; for it involves the direct execution of the policies formulated by the higher officers and is also the first point of direct contact with the users of the forest. An administration stands or falls according to the caliber of its *men on the ground*. It is useless to formulate elaborate rules and regulations, to issue stimulating circular letters, etc., if the executive personnel is not developed to carry them out. From the business standpoint too, the profitableness of a forest depends, in large measure, upon the enterprise of the executive in charge.

The supervisor must not be overloaded — this refers not only to his technical duties, but also to the malpractice of making the supervisor a policeman as well.* This is the reason why supervisors and rangers should not be deputy sheriffs. Another reason is because they may not receive any pay for extra-federal services.

The supervisor should, obviously, be a technically trained man in order to do justice to his position and its possibilities.

The supervisor must not be burdened with purely mechanical work, *i.e.*, he must have adequate clerical assistance to take care of correspondence, records, accounts, etc.

One of the most important parts of forest administration is the carrying out of the working plan and taking care of its control and revision. This needs, on the part of the supervisor, a knowledge (1) of local conditions, (2) of methods of forest organization. The former is achieved by every supervisor. The latter is asking too much — the field is too specialized, and means too much extra work for the supervisor, to be done by him without adequate assistance. Hence forest organization is properly the task of a central office with a corps of trained men.

Where there is no special office for forest organization, there should be, at least, certain higher officers especially entrusted with the direction of forest organization, with a staff of helpers to do the necessary field-work.

The deputy supervisor, the forest examiner and even the forest assistant, all assist in the executive work under the supervisor's immediate direction.

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* See "Administration of a Prussian Forest," For. Quart., Vol. XI, No. 1.

129. Protection. — The protective service comprises the rangers and their assistants. At first the rangers were chiefly occupied in preventing poaching ("King's Foresters"), fire, theft of wood, etc. Gradually, technical duties have devolved upon them. The work which they perform varies greatly in different countries and under different conditions and with the training and ability of the individual. The ranger must at least be able to execute the technical directions of the supervisor and to judge when these are insufficient and further directions must be obtained.

The larger the ranger district and the more extensive the management, the more independent and responsible is the position of the ranger until it may approach that of the true head ranger, who is a *supervisor-in-parvo.* The increasing education of the ranger has led, abroad, to the placing of additional responsibility on him and to increasing the size of his district — as far as is compatible with the intensity of management.

Under the District Ranger scheme the proper education of the incumbent officers is essential. This means efficiency. It also means increased expense for better salaries. Hence, the employment of mere woodsmen, untrained in technical lines, is cheaper. This is known as the Forest Guard system, and is what we find today in the U. S. Forest Service — disregarding the slight training at "Ranger Schools" which some of our rangers have enjoyed. The efficiency of this system depends directly upon the personal equation.

In Europe, the District Ranger system is increasing because of the increasing intensity of management. Even those states where the other system still exists are planning for a change to the former, *by providing for the education of men already in the service.*

Only in small administrative units is this system of untrained rangers desirable since the supervisor or his technical assistant cannot, as a rule, give their personal attention to the details of a ranger's work. It is also indicated under *very* extensive management; indeed, with respect to the low income usual under such conditions, it is often necessitated there in order to keep down expenses.

Various combinations of the two systems are found. Thus, in France, the well-educated ranger has untrained assistants. We, too, have this. The District Ranger is assisted by guards — chiefly, however, for fire patrol and improvement work (roads, trails, telephone, cabins, etc.).

Rangers, then, should not be over-burdened with executive work, especially not with such executive work as is beyond their capacity and training; but they should be trained to perform the simpler executive functions which are their proper sphere and which they can perform more economically than anyone else.

130. Special Detail. — This includes certain lines of work which, in their very nature, require the use of specially trained men. Such work cannot be efficiently executed by the regular personnel and it becomes necessary, therefore, to detail men especially to it. The attempt to have untrained men handle this work may be seemingly more economical but in reality it is more expensive; for the work must, in many cases, be done over by a trained personnel.

Among the many kinds of work requiring special detail for efficient execution may be cited:

(*a*) Survey and improvement work of a technical character.

(*b*) Working plans. Forest organization is a technical subject requiring special training and capabilities. This is true even of the field-work of forest organization — forest surveys. Experience has shown that for good results the work must be done by special parties, *not* as a part of the ranger's district work — however alluring this may seem from the standpoint of economy. Both here and abroad the preparation of working plans is being placed pretty generally in the hands of especially detailed men. However, the supervisor has general control of the party while they are on his forest. He maintains, or should maintain, an active advisory and coöperative attitude which is the more important, since, without it, the party is deprived of his valuable local knowledge and experience.

The same is true of the ranger in whose district the party may be at work; indeed, the district ranger is often assigned to the party — frequently at his own request — in order to gain familiarity with forest survey methods.

(*c*) *Investigations or Research.* — The research work on the forests must be coördinated and this involves centralized control. The district office issues the necessary instructions for this most important work. Usually, the experiment stations are the *foci* of investigative activity in the district.* These have, of course, their own specially trained personnel and operate under an annual program formulated by the District Investigative Committee and approved by the Central Investigative Committee in Washington. In addition, forest assistants or forest examiners attached to certain forests may pursue research work independently of the experiment station. Experience has shown that here, too, routine work often impedes research and seriously reduces in value the results secured.† Investigative work requires, for its full fruition, special details. Ambitious officers should, however, be encouraged to do work along these lines as they have time and opportunity or where such work is urgently needed.

131. Distribution According to Area. — The activities of the administrative units must be delineated not only according to the subject of work but also according to area. A conflict in area is just as much to be avoided as one in subject. The area is to be sufficient so as to require the full working ability of an average man; temporary increase in the amount of work can be met:

(*a*) By temporarily increased activity on the part of the forest officer.

(*b*) By assignment of temporary assistants.

The central office invariably comprises the whole country and is located at the capital. The districts usually coincide with the political boundaries of certain states or groups of states.

Where the district officers act as inspectors, each of a certain group of forests, the whole district is not made larger than the personnel can cover; figuring that each district officer shall visit *each* forest within his group several times a year, besides handling his routine work in the district office. Means of communication and the size and accessibility of the individual forest play an important part in deciding upon the size of districts. Size and accessibility tend to counterbalance each other inasmuch as mountain forests which by reason of their topography are more inaccessible and hence justify smaller districts are, at the same time, less intensively managed, allowing larger sized districts.

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* See Pearson, G. A., "The Administration of a Forest Experiment Station," For. Quart., Vol. XII, No. 2, pages 211–222.

† A good example of this is the gathering of data for volume, growth, stand, and yield tables. For such data local executive officers can seldom be depended upon.

In Europe the district of each inspecting assistant district forester comprises about 60,000 acres. Within the district proper there are usually 300,000 acres, depending upon the number of inspecting assistants.

In the United States, the seven districts, on June 30, 1918, comprised 152 National Forests with a total net area of 155,374,602 acres. This is an average of about 22,000,000 acres in each district.

Considerations similar to those given for districts, govern in determining the area of the individual executive unit, and, in addition, the following:

(*a*) Does the supervisor or head-ranger system exist on the forest?

(*b*) Of what caliber are the executives and what preparatory training have they had?

(*c*) What is the nature of the business, *e.g.*, small business — small timber sales, many grazing permittees, greatly increase the amount of routine.

The proper area of an executive unit is to be so determined with reference to these and the aforementioned considerations, that the executive may be fully responsible for his administration in all its details and may be independent of his subordinates' judgment in passing upon the efficiency of the work on every part of his forest. The deputy forest supervisor is not to be considered a subordinate in this respect. When the work on a forest is very complex, men may be assigned to assist the supervisor in special lines — *e.g.*, timber sales, grazing; in their particular lines they represent the supervisor's office whenever they go in the field and speak with his authority, though they are, of course, responsible to him.

In Europe the size of the average executive unit is about 6000 acres. In the United States the 152 National Forests average 1,022,200 acres each.

In Europe increasing intensity of management has made for decreased size of executive units. However, experience has taught that there is a distinct limit in this direction, beyond which further reduction in area is uneconomical. It is poor policy to have a high-priced official doing work which a cheaper subordinate is equally capable of performing. The tendency in European forest administration is towards a better training of the ranger force, the assigning of adequate clerical assistance and the fullest possible utilization of all modern means of communication (automobiles!). This tendency, will, undoubtedly, lead to an increase in the size of the executive units. Even now, a forest of less than 5000 acres is considered uneconomically small unless the forest is very much split up. Schwappach * says: "7200 acres can, other things being equal, be quite intensively administered by a single executive, and, under simple conditions, in level country, an area of 12,000 acres is not too large."

The choice of headquarters is a very important matter. It must be centrally located with respect to the forest, and, at the same time, be accessible to forest users and offer to the supervisor's family opportunities for social and religious intercourse and for the proper education of children. However much the young bachelor may revel in the freedom of a headquarters remote from civilization, he will be more than likely to change his opinion when married and with a family to bring up.

In deciding upon the area of ranger districts the following conditions govern:

(1) The topography and the kind of timber, *i.e.*, open or dense, softwood or hardwood, etc.
(2) The geography of the forest, *i.e.*, configuration.
(3) Intensity of management and degree of settlement.

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* In Lorey, "Handbuch der Forstwissenschaft," Vol. III, 3rd edit., 1912.

(4) Fire danger.
(5) Training of the ranger.
(6) Whether the district ranger scheme is in effect or not.

In Europe the average size of a ranger district is about 1440 acres. In the United States proper, it approximates 60,000 acres. Rangers should be stationed in or close to their districts; with them the demands for an agreeable social environment are not so pressing. A district ranger can handle a larger area than the unassisted ranger. In certain districts winter work is out of the question. All but the regular rangers are laid off during the winter; in the summer they are given adequate assistance to handle their districts which are usually larger than is the case where field-work is possible the year round.

132. Personnel Relations. — Under this heading come (1) appointment, (2) promotions, and (3) pay. The subject of qualifications might be added but it will suffice to quote Dr. Schenck's famous definition of what a forester should be. "A forester," he said, "should stand the life in the woods like a tree and should stand the knocks in the mill like a log, lest he go to waste with the culls." *

133. Appointment. — There are two possible ways of recruiting personnel in forest administration. (*a*) By examination. (*b*) By arbitrary appointment. The former, exemplified by the system of civil service of which the federal forest service is a part, safeguards the employees from political influence and ensures stability regardless of changes in the party in power. The arbitrary appointment *may* result in higher efficiency but, in complex organizations, such as the national forest administration, employing over 3000 men, it is apt to be bound up with injustice to the individual, with party politics, and even with graft.

Admission to the government service is, with the rare exceptions of experts, dependent upon the passing of examinations.

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* See also, Pinchot, G., "The Training of a Forester," J. B. Lippincott, Philadelphia, Pa., 1914, especially pages 63–71. Also Redington, P. G., "The Place of a Forest Supervisor in the Community," American Forestry, March, 1914, pages 182–184.

For the United States Forest Service these are held by the Civil Service Commission and are subject to its rules and regulations. The most general entrance examination is that of forest assistant. The passing of this single examination enables promotion to any position in the service. The papers are prepared and marked by officers of the service, chiefly in Washington.

In Europe, three examinations are generally requisite for entrance into the administrative service. At government forest schools the professors (who are also government forest officers) themselves conduct the preliminary examinations. In some cases * the examinations are held by a commission composed of higher officers. It has been found that these higher officers are not as well qualified to judge the technical knowledge of the applicants as are the professors, who, in the nature of things, are more conversant with important technical developments. Furthermore, the examination must, in a measure, be based upon the ground covered in the school's curriculum.

The final examinations † are always conducted by higher officials of the service.

Examinations for the ranger service are, in the United States, also conducted by the Civil Service Commission (assistant forest ranger examination). The papers are prepared in Washington but are marked by the respective district forester and his assistants.

In Europe an examination is omitted where the forest guard system obtains.‡ Where there are ranger schools § an examination is held at the completion of the course. In certain European states, examinations are also required for the attainment of ranger positions in communal and private forests.

Admission to the government forest service is by no means a guarantee of employment. This is true both here and abroad.*

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* See "The Prussian Forest Service," Part I, For. Quart., Vol. XI, No. 1, pages 42–53.

† See For. Quart., Vol. XI, No. 1, page 47.

‡ See Article 129.

§ See For. Quart., Vol. XI, No. 1, pages 50–53.

The forest assistant in the Forest Service of the United States enters upon a two-year apprenticeship under an experienced ranger.

134. Promotion. — In the interest of the service and of the forest officers, it is necessary that promotion to higher positions be according to a just and equitable system which avoids even the semblance of arbitrariness and nepotism.

Three main methods of judging fitness for promotion are:

(1) The results of examinations.
(2) Length of service or seniority.
(3) Special qualifications within and without the service.

The first method — that of examinations — although it constitutes a fairly good basis for judging the knowledge of the applicant, is not an index as to whether the candidate is really qualified for the demands of the position; this drawback becomes more pronounced the longer the time since the examination was passed.

From the pedagogic standpoint it is hardly necessary to point out the unsatisfactory index to ability furnished by examinations — even in highly theoretical subjects. How much more so is this true of a subject like forestry, combining in a rare degree high technical and practical qualifications!

The scheme of requiring an examination before promotion to a higher position, or at least to certain higher positions, has been tried in forest administration (Hannover) but without satisfactory results since, in the first place, formal examinations are scarcely suitable for men of advancing years, smacking, as they do, of the classroom; and, in the second place, it is exceedingly difficult to combine the multiplicity of demands made upon a higher administrative position into a single suitable examination. A better test would seem to be the incumbent's record in the position held. His incumbency will, ordinarily, furnish abundant evidence as to his fitness for a higher office. The stimulus for further study which examination for promotion furnishes is not sufficiently advantageous to offset the disadvantages mentioned. The right kind of man will continue to study and improve himself anyway.

(2) Promotion according to length of service is based on the presumption that those who have been in the service the longest time have gathered the greatest store of experience and hence are best fitted for promotion; that, furthermore, they are more entitled to it than are newer incumbents. The method avoids any seeming arbitrariness in promotions and accords with the view that after a certain length of service a man deserves advancement. The great disadvantage of this method lies in the facts that:

(*a*) The higher positions demand certain extra qualifications which are apt to be lacking in the majority of men who reach the intermediate places.

(*b*) Promotion by seniority is apt to postpone the reaching of higher positions to an age when the incumbents may lack the mental freshness and initiative so necessary for constructive work, and, perhaps, the bodily vigor requisite for arduous field-inspection duty. By basing promotion to high positions on seniority the incumbents are apt to change too frequently for the good of the service — that is, they seek retirement just when they have "learned the ropes."

This method, therefore, will not suffice in all cases.

(3) Where special qualifications of an incumbent are made the basis of promotion, it is necessarily according to the judgment of some superior officers. It may be entirely arbitrary, as in the reputed "one-man" methods of the late James Hill in the personnel of the Great Northern Railway. Usually, however, a committee of superior officers will, periodically, consider the qualifications of all subordinates and make a "slate" for promotion. At the same time, this review serves as a basis of judging whether incumbents are satisfactorily filling their present positions or whether demotion or even dismissal (or forced resignation) are in order.

Modern methods of efficiency demand that incumbents be informed not only of satisfactory work but also of shortcomings in order that they may be given the chance to overcome their deficiencies. Needless to say the communication of such adverse findings requires the greatest tact. The "slate" for promotion is published in France (*tableau d'avancement*) and the committee charged with promotions (*conseil d'avancement*) consists in part of subordinate officers, two representatives being chosen for each subordinate position up to and including the *brigadiers* (rangers); within their own rank these representatives can vote, for other ranks only advise.

The very highest positions and also the positions of especial difficulty are always filled by direct appointment of particularly well qualified men.

In conclusion it would seem expedient to:

(*a*) Follow the method of examination for filling the subordinate positions; grading the men according to the marks achieved in the examination and appointing them in that order.

(*b*) Promote to intermediary positions (executive, protective, etc.) according to seniority of service.

(*c*) Promote to higher positions (inspective) according to promotion "slates" drawn up by a committee of higher officers.

(*d*) Promote to highest positions (directive) by special appointment (*e.g.*, the position of Forester in the Forest Service is filled by presidential appointment, although the incumbent must have passed a civil service examination).

Transfer from one post to another, where the move is in the nature of a promotion, should never be without the consent of the promoted except where it is necessary "for the good of the service."

135. Pay. — Certain general principles of remuneration for services may be formulated. These, rather than the presentation of statistics of actual salaries paid, are the object of this article.*

In the first place, the time of initial employment without compensation should be as short as possible, preferably zero. Second, there should be a proper relation in the pay of the different positions. Third, the salary paid should be sufficient so that the incumbent and his family may live thereon in a manner commensurate with the dignity of the position and of the organization which they represent. He should be able to live without enforced recourse to private means, and to educate his children properly. Fourth, the forest officer should, before too advanced an age, attain the right of retirement on an adequate pension.

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* Woolsey, T. S., Jr., in "Forest Service Revenue and Organization," For. Quart., Vol. XIV, No. 2, pages 188–235, gives on page 207, a "Comparative Table of Main Titles and Salaries" in the United States, France, Austria,

One man does not make a forest service but the whole service is often judged by the individual representative encountered. If through insufficient salary he is forced into a penurious form of living it may react unfavorably on the service.

For the government service a fifth condition should be added; the pay should approximate that received for similar services in private employ. So far our government technical services have been a procession. Men enter, are trained to efficiency and then accept more lucrative positions elsewhere. This is false economy disguised as an apparent saving. Though the salary roll may be lower, how about the costly mistakes made by inexperienced men, the loss in prestige and efficiency due to constantly changing personnel? "No man," says Carlyle, "works save under conditions." To the young unmarried man, the forest assistant's initial $1200 a year seems bounteous. Ten years later, with wife and one or more children, he finds that he cannot live on his salary — and for his family's sake he leaves the service for a more lucrative position, hard as the change may be. Surely, this is not good for the *ésprit de corps* for which the United States Forest Service is justly famous. Why should the French Forest

British India and Prussia. The following salaries are given for the U. S. Forest Service:

I. Washington Office	Forester	$5000 per annum	
	Assistant Forester	3000–3500	*N. B.* Since July 1, 1917, all salaries from $1200 to $1800 per annum have been increased 5 per cent, all those under $1200 have been increased 10 per cent.
	Forest Inspector	2700–3200	
II. District Office	District Forester	3000–3200	
	Assistant District Forester	2700±	
	Forest Examiner	1400–1800	
	Forest Assistant	1200–1400	
III. National Forest	Supervisor	1800–2400	
	Deputy Supervisor	1400–1800	
	Forest Ranger	1200–1500	
	Assistant Forest Ranger	1100+	

Service, for example, command the services of the best foresters in the country and maintain them on its rolls throughout their active lives? Is our patriotism less pure; is our ideal of service less high? The American Forest Service of today is too largely a training ground — a costly one if efficiency and progressive work count in government as well as in private enterprise.

Two systems of increasing pay are possible aside from arbitrary increases or "promotions." In one, the advance to higher salary is automatic upon completing a certain term of service or reaching a certain rank. In the other, only a certain percentage of the incumbents of each position are entitled to the increased pay, and vacancies occur only through promotion.

Forest officers of the executive and protective service are, from the nature of their occupation, required to live in small communities or even remote from other habitations. It is necessary, therefore, that they be furnished by the service with proper dwellings and places of business. This has been recognized by our forest service in the construction of ranger cabins. Supervisors are but rarely furnished with houses; in fact, only when suitable dwellings cannot be rented by them. Rangers should be given free pasturage (in addition to forage allowance) and it is expedient to have some arable land in connection with the ranger stations for the production of garden truck. Where fodder is raised by rangers in considerable quantities, proportionate deduction is made from the forage allowance.

A source of increased expense arises from the frequent necessity of providing for the education of the children by means of private tutors if schools are too distant. In certain cases this has led to a supervisor seeking transfer from an otherwise very desirable post. Medical help, also, is more difficult of access, more expensive and less efficient; finally, many æsthetic enjoyments, such as theatres and concerts, must be foregone as well as agreeable social intercourse. There is, further, very little opportunity for participation in religious exercises. These considerations have led, in Europe, to the granting of additional emoluments in the form of free dwellings, arable land, free conveyance, free fuel, and certain incomes from fish and game.

These emoluments, in part, are still in force; however, the modern money-basis of life, the necessity of equality in pay of different posts of the same grade, is putting them in abeyance. More and more the old system of making emoluments a part of the salary is being displaced by granting pay to the full value of the emoluments and charging the incumbent rent for house, arable land, etc. In return, he is granted reimbursement for upkeep of wagon or automobile (mileage for the latter) and subsistence when away from his official station.

APPENDIX

TABLE 1

SURVEYOR'S MEASURE (LINEAR)

1 link = 0.01 chain = 0.66 foot = 7.92 inches.
100 links = 1.00 chain = 4 rods = 66 feet.
80 chains = 1.0 mile = 320 rods = 5280 feet.

TABLE 2

SURVEYOR'S MEASURE (SQUARE)

1 acre = 160 sq. rods = 10 sq. chains = 43,560 sq. feet.
40 acres = a square the side of which is ¼ mile.
640 acres = 1 sq. mile, or section.
36 sections = 1 township = 23,040 acres.

TABLE 3

Area of triangle = ½ base × altitude.

$$\text{Area of circle} = \pi r^2 = 3.1416\, r^2 = \frac{\pi}{4} D^2 = 0.7854\, D^2.$$

Radius of circle whose area = 1 acre = 118 feet (approx.)
Radius of circle whose area = ½ acre = 83 feet (approx.)
Radius of circle whose area = ¼ acre = 59 feet (approx.)

TABLE 4

USEFUL EQUIVALENTS AND CONVERTING FACTORS *

1 cord (fuel wood averaging 5″ or less in middle diameter) size of pile 4′ × 4′ × 8′	= 333⅓	bd. feet
1 cord (fuel wood averaging 6″ or more in middle diameter) size of pile 4′ × 4′ × 8′	= 500	"
1 cord of spruce pulp-wood	= 560	"
1 telephone pole 7″ × 30′	= 60	"
1 telephone pole 9″ × 30′	= 100	"
1 standard tie 6″ × 8″ × 8′	= 30	"
1 tie 7″ × 9″ × 8′	= 35	"
1 post 6″ × 7′	= 7	"
1 cubic foot (round timber)	= 6	"

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* Taken from "The National Forest Manual," Silviculture Section, p. 64, 1915.

TABLE 5

VOLUME OF SOLID WOOD IN STACKS

4 ft. high, 8 ft. long, and 10 in., 12 in., 14 in., etc. wide

Length of stick.	1st class: small diameter over 5.5 inches.	2nd class: small diameter 2.5 to 5.5 inches.	3rd class: small diameter 1.0 to 2.5 inches.	1st and 2nd classes mixed.	2nd and 3rd classes mixed.
	CUBIC FEET.				
Inches.					
10	19.50	17.50	14.00	18.50	15.75
12	23.50	21.00	16.00	22.25	18.50
14	27.32	24.50	19.00	25.91	21.75
16	31.00	28.50	21.50	29.75	25.00
18	35.00	32.00	24.30	33.50	28.15
20	37.50	35.00	27.00	36.25	31.00
22	42.20	39.00	30.00	40.60	34.50
24	46.02	42.00	32.70	44.01	37.35
26	50.00	46.00	35.20	48.00	40.60
28	53.21	49.00	38.00	51.11	43.50
30	57.00	53.00	41.00	55.00	47.00
Feet.					
3	68.50	63.00	50.00	65.75	56.50
4	88.92	82.42	63.62	85.67	73.02
5	108.50	101.50	78.00	105.00	89.75
6	128.50	120.00	92.30	124.25	106.15
7	149.55	138.05	106.41	143.80	122.23
8	170.00	165.00	119.90	167.50	142.45
9	190.00	175.00	133.50	182.50	154.25
10	211.00	193.00	147.50	201.00	170.25
11	230.00	210.50	161.20	220.25	185.85
12	250.00	228.00	175.00	239.00	201.50
13	269.00	245.50	189.00	257.25	217.25
14	287.50	262.50	203.00	275.00	232.75

Raphael Zon in For. Quart., Vol. I, No. 4, page 133.

TABLE 6

SCRIBNER LOG RULE[1]

(Decimal "C")[2]

Diameter in inches.	Length in feet.						Diameter in inches.
	6	8	10	12	14	16	
	Contents in board feet.						
6	0.5	0.5	1	1	1	2	6
7	0.5	1	1	2	2	3	7
8	1	1	2	2	2	3	8
9	1	2	3	3	3	4	9
10	2	3	3	3	4	6	10
11	2	3	4	4	5	7	11
12	3	4	5	6	7	8	12
13	4	5	6	7	8	10	13
14	4	6	7	9	10	11	14
15	5	7	9	11	12	14	15
16	6	8	10	12	14	16	16
17	7	9	12	14	16	18	17
18	8	11	13	16	19	21	18
19	9	12	15	18	21	24	19
20	11	14	17	21	24	28	20
21	12	15	19	23	27	30	21
22	13	17	21	25	29	33	22
23	14	19	23	28	33	38	23
24	15	21	25	30	35	40	24
25	17	23	29	34	40	46	25
26	19	25	31	37	44	50	26
27	21	27	34	41	48	55	27
28	22	29	36	44	51	58	28
29	23	31	38	46	53	61	29
30	25	33	41	49	57	66	30
31	27	36	44	53	62	71	31
32	28	37	46	55	64	74	32
33	29	39	49	59	69	78	33
34	30	40	50	60	70	80	34
35	33	44	55	66	77	88	35
36	35	46	58	69	81	92	36

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[1] Taken from "The Woodsman's Handbook."

[2] The total scale is obtained by multiplying the figures in this table by 10. Thus the contents of a 6-inch 8-foot log are given as 0.5, so the total scale is 5 board feet. A 30-inch 16-foot log is given as 66, or a total scale of 660 board feet.

TABLE 7

CLARK'S INTERNATIONAL LOG RULE[1]

Diameter in inches.	Length in feet.												
	8	9	10	11	12	13	14	15	16	17	18	19	20
	Contents in board feet.[2]												
6	10	10	10	15	15	15	20	20	20	25	25	30	30
7	15	15	15	20	20	25	25	30	30	35	35	40	45
8	20	20	25	25	30	35	35	40	45	45	50	55	60
9	25	30	30	35	40	45	50	50	55	60	65	70	75
10	30	35	40	45	50	55	60	65	70	75	85	90	95
11	40	45	50	55	65	70	75	80	90	95	105	110	115
12	50	55	65	70	75	85	90	100	105	115	125	130	140
13	60	65	75	85	90	100	110	120	130	140	145	155	165
14	70	80	90	100	110	120	130	140	150	160	175	185	195
15	80	90	105	115	125	140	150	160	175	185	200	215	225
16	95	105	120	130	145	160	170	185	200	215	230	245	260
17	105	120	135	150	165	180	195	210	225	245	260	275	295
18	120	135	155	170	185	205	220	240	255	275	295	310	330
19	135	155	175	190	210	230	250	270	290	310	330	350	370
20	150	170	195	215	235	255	275	300	320	345	365	390	410
21	170	190	215	235	260	285	305	330	355	380	405	430	455
22	185	210	235	260	285	315	340	365	390	420	445	475	500
23	205	230	260	285	315	345	370	400	430	460	490	520	550
24	225	255	285	315	345	375	405	440	470	500	535	565	600
25	245	275	310	345	375	410	445	475	510	545	580	615	650
26	265	300	335	370	405	445	480	520	555	595	630	670	705
27	290	325	365	405	440	480	520	560	600	640	680	725	765
28	310	350	395	435	475	520	560	605	645	690	735	780	825
29	335	380	425	470	510	560	605	650	695	740	790	835	885
30	360	405	455	500	550	600	645	695	745	795	845	895	950
31	385	435	485	540	590	640	695	745	800	850	905	960	1015
32	410	465	520	575	630	685	740	795	850	910	965	1025	1080
33	440	495	555	610	670	730	790	850	905	970	1030	1090	1150
34	470	530	590	650	715	775	840	900	965	1030	1095	1160	1225
35	495	560	625	690	755	825	890	955	1025	1095	1160	1230	1300
36	525	595	665	735	800	875	945	1015	1085	1160	1230	1305	1375
37	560	630	705	775	850	925	1000	1075	1150	1225	1300	1380	1455
38	590	665	745	820	895	975	1055	1135	1210	1295	1375	1455	1535
39	620	705	785	865	945	1030	1110	1195	1280	1365	1450	1535	1620
40	655	740	825	910	995	1085	1170	1260	1345	1435	1525	1615	1705
41	690	780	870	960	1050	1140	1230	1325	1415	1510	1605	1700	1795
42	725	820	915	1010	1100	1200	1295	1390	1490	1585	1685	1785	1885
43	760	860	960	1060	1155	1260	1360	1460	1560	1665	1770	1870	1975
44	800	900	1005	1110	1215	1320	1425	1530	1635	1745	1855	1960	2070
45	835	945	1055	1160	1270	1380	1490	1600	1715	1825	1940	2050	2165
46	875	990	1100	1215	1330	1445	1560	1675	1790	1910	2030	2145	2265
47	915	1035	1150	1270	1390	1510	1630	1750	1870	1995	2120	2240	2365
48	955	1080	1205	1325	1450	1575	1700	1830	1955	2085	2210	2340	2470

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[1] By permission of Judson F. Clark.

[2] The contents are for logs sawn with band saws cutting one-eighth inch kerf.

TABLE 8

Scale Values for Biltmore Stick *

(6 to 30 inches)

Calculated from the formula $S = \frac{d(a-t)}{\sqrt{a(d+a)}}$ in which S = the scale value, d = the diameter of the tree, a = arm's length, t = thickness of the stick.

Values for S, when $t = \frac{1}{4}$ inch.

Diameter.	a = 23 inches.	a = 24 inches.	a = 25 inches.	a = 26 inches.
6	5.28	5.31	5.34	5.36
7	6.06	6.09	6.13	6.15
8	6.82	6.85	6.90	6.93
9	7.54	7.59	7.64	7.71
10	8.25	8.31	8.36	8.41
11	8.94	9.01	9.07	9.12
12	9.62	9.69	9.76	9.83
13	10.28	10.35	10.42	10.51
14	10.92	11.00	11.08	11.17
15	11.54	11.63	11.72	11.82
16	12.15	12.25	12.36	12.46
17	12.75	12.86	12.98	13.08
18	13.33	13.46	13.59	13.70
19	13.90	14.04	14.18	14.30
20	14.46	14.61	14.75	14.89
21	15.01	15.17	15.32	15.47
22	15.55	15.72	15.87	16.05
23	16.09	16.26	16.42	16.60
24	16.62	16.79	16.95	17.14
25	17.13	17.31	17.48	17.67
26	17.62	17.82	17.99	18.20
27	18.11	18.32	18.52	18.72
28	18.60	18.81	19.04	19.24
29	19.08	19.30	19.54	19.74
30	19.56	19.78	20.03	20.22

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* Calculated by Slide Rule (and hence correct only to nearest 0.02-inch).

TABLE 9

Area of Circles in Square Feet

Diameter.	Tenths of Inches.									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	Area — Square Feet.									
Inches.										
1	0.006	0.007	0.008	0.009	0.011	0.012	0.014	0.016	0.018	0.020
2	0.022	0.024	0.026	0.029	0.031	0.034	0.037	0.040	0.043	0.046
3	0.049	0.052	0.056	0.059	0.063	0.067	0.071	0.075	0.079	0.083
4	0.087	0.092	0.096	0.101	0.106	0.111	0.115	0.121	0.126	0.131
5	0.136	0.142	0.147	0.153	0.159	0.165	0.171	0.177	0.184	0.190
6	0.196	0.203	0.210	0.216	0.223	0.230	0.238	0.245	0.252	0.260
7	0.267	0.275	0.283	0.291	0.299	0.307	0.315	0.323	0.332	0.340
8	0.349	0.358	0.367	0.376	0.385	0.394	0.403	0.413	0.422	0.432
9	0.442	0.452	0.462	0.472	0.482	0.492	0.503	0.513	0.524	0.535
10	0.545	0.556	0.568	0.579	0.590	0.601	0.613	0.625	0.636	0.648
11	0.660	0.672	0.684	0.697	0.709	0.721	0.734	0.747	0.760	0.772
12	0.785	0.799	0.812	0.825	0.839	0.852	0.866	0.880	0.894	0.908
13	0.922	0.936	0.950	0.965	0.979	0.994	1.009	1.024	1.039	1.054
14	1.069	1.084	1.100	1.115	1.131	1.147	1.163	1.179	1.195	1.211
15	1.227	1.244	1.260	1.277	1.294	1.310	1.327	1.344	1.362	1.379
16	1.396	1.414	1.431	1.449	1.467	1.485	1.503	1.521	1.539	1.558
17	1.576	1.595	1.614	1.632	1.651	1.670	1.689	1.709	1.728	1.748
18	1.767	1.787	1.807	1.827	1.847	1.867	1.887	1.907	1.928	1.948
19	1.969	1.990	2.011	2.032	2.053	2.074	2.095	2.117	2.138	2.160
20	2.181	2.204	2.226	2.248	2.270	2.292	2.315	2.337	2.360	2.383
21	2.405	2.428	2.451	2.475	2.498	2.521	2.545	2.568	2.592	2.616
22	2.640	2.664	2.688	2.712	2.737	2.761	2.786	2.810	2.835	2.860
23	2.885	2.910	2.936	2.961	2.986	3.012	3.038	3.064	3.089	3.115
24	3.142	3.168	3.194	3.221	3.247	3.275	3.301	3.328	3.355	3.382

Diameter.	Area.	Diameter.	Area.	Diameter.	Area.	Diameter.	Area.	Diameter.	Area.
Inches.	*Sq. ft.*	*Inches.*	*Sq. ft.*	*Inches.*	*Sq. ft.*	*Inches.*	*Sq. ft.*	*Inches.*	*Sq. ft.*
25	3.41	32	5.59	39	8.30	46	11.54	53	15.32
26	3.69	33	5.94	40	8.73	47	12.05	54	15.90
27	3.98	34	6.30	41	9.17	48	12.57	55	16.50
28	4.28	35	6.68	42	9.62	49	13.10	56	17.10
29	4.59	36	7.07	43	10.08	50	13.64	57	17.72
30	4.91	37	7.47	44	10.56	51	14.19	58	18.35
31	5.24	38	7.88	45	11.04	52	14.75	59	18.99

TABLE 10

SAMPLE VOLUME TABLE FOR WHITE PINE IN NEW HAMPSHIRE

(From the "Woodsman's Handbook," Table No. 12.)

Breast-height diam. (in.).	Height of tree (feet).											Basis (trees).
	30	40	50	60	70	80	90	100	110	120		
	Volume in board feet.											
5	8	12	15	...	...	...	...	...	...	...	....	7
6	13	20	23	27	29	...	...	...	...	...	....	41
7	18	28	34	39	44	...	...	...	...	...	....	75
8	24	36	45	53	62	...	...	...	...	...	....	128
9	32	44	56	69	81	93	...	...	...	...	....	156
10	41	53	70	85	102	119	138	...	...	...	....	177
11	..	63	84	103	126	147	168	...	...	...	....	164
12	..	73	100	125	151	177	200	228	245	...	....	146
13	..	84	117	148	180	210	238	270	293	...	....	137
14	..	95	137	173	210	243	277	312	348	...	....	91
15	..	105	158	200	241	282	321	362	406	...	....	61
16	..	..	181	230	277	323	370	415	470	...	....	88
17	..	..	209	261	313	368	421	471	540	...	....	70
18	..	..	238	297	352	411	475	531	610	688	....	68
19	..	..	270	336	393	460	530	598	682	763	....	44
20	..	..	302	379	436	506	583	660	750	840	....	35
21	..	..	...	425	480	553	634	720	820	918	....	23
22	..	..	...	...	522	597	681	779	887	990	....	16
23	..	..	...	...	566	639	727	834	958	1065	....	19
24	..	..	...	...	...	674	769	889	1030	1135	....	9
25	..	..	...	...	...	706	809	942	1105	...	....	12
26	..	..	...	...	...	737	846	994	1180	...	....	11
27	..	..	...	...	...	...	...	1046	...	...	....	....
												1578

The volume given is actual saw cut. Sixty per cent was round-edged, and forty per cent squared; seventy per cent, one-inch boards, and thirty per cent, 2½-inch plank.

TABLE 11

SAMPLE VOLUME TABLE FOR YELLOW BIRCH IN NEW HAMPSHIRE

Volume in Board Feet

Diameter, breast high.	Number of 16-foot logs.							Diameter inside bark of top.	Stump height.	Basis.
	½	1	1½	2	2½	3	3½			
	Volume — board feet in tens.									
Inches.								Inches.	Feet.	Trees.
7	1	1	2	3	......	......	......	6	2.1	2
8	1	2	2	3	4	......	......	6	2.1	8
9	1	2	3	4	5	......	......	7	2.2	24
10	2	3	4	5	6	......	......	7	2.2	43
11	2	4	5	6	8	......	......	8	2.2	44
12	3	5	6	8	9	......	......	8	2.2	45
13	3	6	8	9	11	......	......	9	2.2	36
14	4	7	9	11	13	14	......	9	2.3	35
15	4	8	11	13	15	16	......	10	2.3	47
16	5	10	13	15	17	18	......	11	2.3	40
17	6	11	15	18	20	21	......	11	2.4	32
18	7	13	17	20	23	25	......	12	2.4	38
19	8	14	20	23	26	28	......	13	2.4	36
20	9	16	22	26	30	33	36	13	2.5	39
21	10	18	25	30	34	37	41	14	2.5	28
22	11	20	27	33	38	42	47	15	2.6	21
23	13	23	30	36	42	48	53	15	2.6	24
24	14	25	33	40	47	53	59	16	2.7	21
25	15	27	36	44	51	58	64	16	2.7	23
26	......	30	40	48	56	63	70	17	2.8	17
27	......	33	44	52	61	69	76	18	2.9	14
28	......	36	48	57	66	74	82	18	2.9	17
29	......	......	52	62	71	80	88	19	3.0	7
30	......	......	57	67	77	86	95	20	3.0	....
31	......	......	......	72	82	92	101	20	3.1	5
32	......	......	......	78	88	98	108	21	3.1	5
										651

Logs scaled as cut, 10 to 16 feet long, by Scribner Decimal *C* rule. Utilization as close as form of tree allowed.

Taken from U. S. Dept. Agric. Bul. 285, "The Northern Hardwood Forest," etc., by E. H. Frothingham.

TABLE 12

SAMPLE YIELD TABLE FOR WHITE PINE[1]

Yield per Acre for Pure, Even-aged, Second-growth Stands

Quality I.

Age.	Average height of dominant trees.	Diameter, breast high, of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.	Age.	Average height of dominant trees.	Diameter, breast high, of average tree.	Number of trees per acre.	Basal area per acre.	Total yield.
Yrs.	Feet.	Ins.		Sq. ft.	Cu. ft.	Yrs.	Feet.	Ins.		Sq. ft.	Cu. ft.
10	7.2	1.7	1728	29	800	60	85.5	12.8	311	278	10,500
15	14.5	2.9	1520	68	1400	65	90.5	13.7	279	286	11,300
20	24.5	4.0	1322	115	2100	70	94.5	14.7	249	293	11,900
25	34.5	5.2	1115	162	3000	75	98.0	15.6	226	300	12,500
30	44.0	6.4	879	196	4000	80	101.5	16.5	207	307	13,000
35	53.0	7.5	710	218	5200	85	105.0	17.4	190	313	13,500
40	61.0	8.6	583	235	6500	90	108.0	18.2	177	319	14,000
45	68.0	9.7	485	249	7700	95	110.5	19.0	165	324	14,400
50	74.5	10.8	408	260	8800	100	113.0	19.8	154	330	14,700
55	80.5	11.8	354	269	9700	....	......	......	.....	......	....
Quality II.											
10	6.0	1.4	2015	20	650	60	74.5	10.7	397	248	8,500
15	12.0	2.2	1834	50	1150	65	79.0	11.6	348	255	9,200
20	19.5	3.2	1626	90	1750	70	83.0	12.4	311	261	9,840
25	28.0	4.1	1420	131	2420	75	86.5	13.3	277	267	10,400
30	36.5	5.1	1192	169	3250	80	90.0	14.1	251	272	10,930
35	44.5	6.1	950	193	4180	85	93.0	14.9	229	277	11,400
40	51.5	7.1	760	209	5130	90	95.5	15.7	210	282	11,850
45	58.0	8.0	633	221	6100	95	98.0	16.4	195	286	12,250
50	64.0	8.9	537	232	7000	100	100.0	17.1	182	290	12,630
55	69.5	9.8	460	241	7800	....	......	......	.....	......	....
Quality III.											
10	4.0	1.0	2408	14	530	60	64.0	8.6	543	219	6,530
15	9.0	1.6	2234	33	900	65	68.0	9.4	465	224	7,160
20	14.5	2.3	2060	60	1350	70	71.5	10.1	412	229	7,760
25	21.0	3.1	1886	98	1850	75	75.0	10.9	361	234	8,320
30	28.5	3.9	1676	139	2450	80	78.0	11.7	318	238	8,820
35	36.0	4.7	1400	167	3100	85	81.0	12.4	288	242	9,300
40	42.5	5.5	1118	183	3780	90	83.0	13.2	258	245	9,750
45	48.5	6.3	900	194	4500	95	85.5	13.8	239	248	10,150
50	54.0	7.0	764	204	5200	100	87.0	14.5	219	251	10,530
55	58.0	7.8	639	212	5870	....	......	......	.....	......	....

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[1] Taken from "White Pine Under Forest Management," by E. H. Frothingham, U. S. Dept. of Agr., Bul. No. 13.

INDEX TO SELECTED VOLUME TABLES

Ash (black). — U. S. D. A., Bul. 299, pp. 85–86 (cu. feet), p. 86 (cords), p. 87 (bd. feet).

Ash (green). — U. S. D. A., Bul. 299, pp. 81–82 (cu. feet), p. 83 (cords), pp. 84–85 (bd. feet).

Ash (white). — U. S. D. A., Bul. 299, p. 78 (cu. feet), p. 79 (cords), pp. 80–81 (bd. feet).

Ash (white). — (Second growth) Vermont Agr. Ex. Sta., Bul. 176, p. 81 (cu. feet).

Aspen. —[1] U. S. D. A., Forest Service, Bul. 93, p. 34 (cu. feet), p. 35 (cords).

Aspen. —[2] U. S. D. A., Forest Service, Bul. 36, p. 113.

Balsam Fir. —[1] U. S. D. A., Bul. 55, p. 50 (cu. feet), p. 51 (cords), pp. 54–55 (bd. feet).

Balsam Fir. —[2] For. Quart., Vol. IX, p. 593.

Basswood. —[1] U. S. D. A., Bul. 285, pp. 55–57 (bd. feet), p. 61 (cu. feet).

Beech. —[1] U. S. D. A., Bul. 285, pp. 49–51 (bd. feet), p. 59 (cu. feet).

Beech. —[2] (Second growth), Vermont Agr. Exp. Sta., Bul. 176, p. 81 (cu. feet).

Birch (white or paper). — U. S. D. A., Forest Service, Circ. 163 (1909), pp. 31–32 (cu. feet).

Birch (yellow). — U. S. D. A., Bul. 285, pp. 47–49 (bd. feet), p. 58 (cu. feet).

Birch (yellow). — (Second growth), Vermont Agr. Exp. Sta., Bul. 176, p. 80 (cu. feet).

Cedar (western red). — "Western Red Cedar in the Pacific Northwest" by J. B. Knapp and A. G. Jackson. Reprint from "West Coast Lumberman," Feb. 1, 1914 and Mar. 1, 1914, by the U. S. Forest Service.

Chestnut. — U. S. D. A., Forest Service, Bul. 96, p. 64 (cords), p. 65 (bd. feet).

Chestnut. — U. S. D. A., Forest Service, Bul. 36, "The Woodsman's Handbook," p. 128.

Chestnut Oak. — See *Oak.*

Cypress (southern). — U. S. D. A., Bul. 272, pp. 70–72 (bd. feet).

Douglas Fir. — U. S. Forest Service, Bul. 36, pp. 154–161.

Gum (sweet, or red). —[1] U. S. Forest Service, Bul. 36, p. 148.

Gum (sweet, or red). —[2] U. S. Forest Service, Bul. 58, p. 31.

Hemlock (eastern). — U. S. D. A., Bul. 152, pp. 31–34 (bd. feet), p. 35 (cu. feet), pp. 36–37 (bark, in cords).

Hemlock (eastern). — Vt. Agr. Exp. Sta., Bul. 161, "Hemlock in Vt.," p. 5.

Hemlock (eastern). — For. Quart., Vol. IV, p. 292.

Hemlock (western). — U. S. D. A., Forest Service, Bul. 33, p. 31.

Hemlock (western). — "Western Hemlock" by E. J. Hanzlik and H. B. Oakleaf. Reprint by U. S. Forest Service, from "Timberman" of October, 1914. (p. unnumbered.) (last page of reprint.)

Hickory. — U. S. Forest Service, Bul. 36, pp. 132–133 (cu. feet).

Hickory. — U. S. Forest Service, Bul. 80, p. 35 (cu. feet).

Incense cedar. — U. S. D. A., Bul. 604, p. 37 (cu. feet), pp. 38–40 (bd. feet).

Juniper. — See *Cedar.*

Larch (western). — U. S. Forest Service, Bul. 36, pp. 166–169.

Maple (sugar, or hard). — U. S. D. A., Bul. 285, pp. 52–54 (bd. ft.), p. 60 (cu. ft.).

Maple (red, or soft). — U. S. D. A., Bul. 285, p. 61 (cu. feet), p. 62 (cords).

Oak (*black*). — U. S. D. A., Forest Service, Bul. 96, p. 62, p. 65.
Oak (*chestnut*). — U. S. D. A., Forest Service, Bul. 96, p. 63, p. 66.
Oak (*red*). — U. S. D. A., Forest Service, Bul. 96, p. 62, p. 65.
Oak (*white*). — U. S. D. A., Forest Service, Bul. 96, p. 63, p. 66.
Pine (*bull, or western yellow*). — U. S. D. A., Bul. 418, p. 43 (bd. feet), pp. 44–45 (bd. ft.).
Pine (*bull, or western yellow*). — For. Quart., Vol. VIII, p. 177.
Pine (*loblolly*). — U. S. D. A., Bul. 11, pp. 53–54 (cu. feet), pp. 54–57 (bd. feet).
Pine (*loblolly*). — N. C. Geol. Surv., Bul. 24.
Pine (*lodge pole*). — U. S. Forest Service, Bul. 36, pp. 170, 171.
Pine (*long-leaf*). — U. S. Forest Service, Bul. 36, p. 151.
Pine (*Norway or red*). — U. S. D. A., Bul. 139, pp. 34–35 (bd. feet), p. 36 (cu. feet).
Pine (*pitch*). — For. Quart., Vol. III, p. 16.
Pine (*short-leaf*). — U. S. D. A., Bul. 308, pp. 56–59 (bd. feet and cu. feet).
Pine (*sugar*). — U. S. D. A., Bul. 426, pp. 37–38 (bd. feet).
Pine (*white, eastern*). — U. S. D. A., Bul. 13, pp. 64–65 (bd. feet), p. 67 (cu. feet), p. 68 (cords).
Pine (*white, eastern*). — For. Quart., Vol. IX, p. 594.
Pine (*white, western*). — U. S. Forest Service, Bul. 36, pp. 176, 177, 178.
Poplar (*yellow*). — U. S. Forest Service, Bul. 36, pp. 139, 140, 141.
Redwood. — U. S. Forest Service, Bul. 38, p. 23 (d. b. h. 14″–27″ only).
Spruce (*eastern red*). — U. S. Forest Service, Bul. 36, p. 126 (cu. feet).
Spruce (*eastern red*). — U. S. D. A., Bul. 544, pp. 69–79 (bd. feet and standards), pp. 79–81 (cu. feet), pp. 82–83 (cords).
Spruce (*eastern white*). — For. Quart., Vol. IX, pp. 590–592.
Spruce (*Engelmann*). — U. S. Forest Service, Bul. 36, pp. 184–186.
Tamarack. — See *Larch*.
Willow (*black*). — U. S. D. A., Bul. 316, pp. 14–18 (bd. feet), p. 19 (cu. ft.)

In addition to the above, a large number of volume tables for trees of all parts of the United States is published in U. S. D. A., Forest Service, Bulletin 36, "The Woodsman's Handbook" by Graves and Ziegler.

INDEX TO SELECTED YIELD TABLES

Birch (*paper, or white*). — U. S. D. A., Forest Service, Circ. 163, p. 36.
Cottonwood. — U. S. D. A., Bul. 24, p. 24.
Douglas Fir. — For. Quart., Vol. XII (1914), pp. 440–451.
Pine (*loblolly*). — U. S. D. A., Bul. 11, pp. 46–47.
Pine (*lodgepole*). — U. S. D. A., Bul. 154, pp. 29–34.
Pine (*short-leaf*). — U. S. D. A., Bul. 244, pp. 40–43.
Pine (*short-leaf*). — U. S. D. A., Bul. 308, pp. 29–32 (cu. feet).
Pine (*short-leaf*). — U. S. D. A., Bul. 308, p. 44 (cords).
Pine (*red, or Norway*). — U. S. D. A., Bul. 139, pp. 21–24.
Pine (*sugar*). — U. S. D. A., Bul. 426, p. 29.
Pine (*eastern white*). — U. S. D. A., Bul. 13, pp. 69–70.
Spruce (*eastern red*). — U. S. D. A., Bul. 544, p. 43.
Spruce (*Norway*). — U. S. D. A., Bul. 544, p. 44.
Willow (*black*). — U. S. D. A., Bul. 316, p. 25.

INDEX TO TAPER, OR FORM TABLES

Ash (*white, green, and black*). — U. S. D. A., Bul. 299, pp. 53–77.
Balsam fir. — U. S. D. A., Bul. 55, pp. 42–49.
Basswood. — U. S. D. A., Bul. 285, pp. 75–79.
Beech. — U. S. D. A., Bul. 285, pp. 69–71.
Birch (*yellow*). — U. S. D. A., Bul. 285, pp. 67–68.
Birch (*paper, or white*). — U. S. D. A., Forest Service, Circ. 163, p. 33.
Hemlock (*eastern*). — U. S. D. A., Bul. 152, pp. 37–43.
Hickory. — U. S. Forest Service, Bul. 80, p. 37 (diam. outside bark).
Maple (*sugar, or hard*). — U. S. D. A., Bul. 285, pp. 72–74.
Pine (*loblolly*). — U. S. D. A., Bul. 11, pp. 57–59.
Pine (*red, or Norway*). — U. S. D. A., Bul. 139, pp. 38–41.
Pine (*short-leaf*). — U. S. D. A., Bul. 308, pp. 60–65.
Spruce (*eastern red*). — U. S. D. A., Bul. 544, pp. 84–93.
Western Red Cedar. — "Western Red Cedar in the Pacific N-W." by J. B. Knapp and A. G. Jackson. Reprint by U. S. Forest Service from "West Coast Lumberman," Feb. 1, 1914 and March 1, 1914.
Willow (*black*). — U. S. D. A., Bul. 316, pp. 21–24.

TECHNICAL ROTATIONS OF IMPORTANT SPECIES

Species.	Locality.		To reach 6-inch d. b. h. (posts), years.	To reach 8-inch d. b. h. (*e.g.* pulp), years.	To reach 11-inch d. b. h. (ties), years.	To reach 14-inch d. b. h. (poles), years.	To reach 18-inch d. b. h. (saw-timber), years.	Authority.
NORTHERN FOREST								
White Pine.......... (pure even-aged stands)	N. H.	Site I	30	35	50	65	90	U. S. D. A. Bul. 13, Tables 3–5.
		Site II	35	45	60	80	over 100	
		Site III	45	55	· 75	95	over 100	
Norway Pine........	Wis.	....	30	40	55	75	110	U.S.D.A.Bul.139, Table 6.
Red Spruce *........	Adirondacks	....	55	65	80	95	135	U.S.D.A.Bul. 544, Tables 10 and 11.
	W. Va.		45	55	70	85	105	
Balsam Fir..........	N. Y.	H'dw'd slope	55	80	125	....	....	U. S. D. A. Bul. 55, Table 13.
		Flat	60	90	150			
		Swamp	75	105	over 150			
	Maine	All types	55	70	105	over 150	....	U.S.D.A.Bul. 55, Table 15.
Beech...............	Mich. & Wis.	....	90	110	140	180	230	U.S.D.A.Bul. 55, Table 15.
	Adirondacks	....	......	......	150	185	225	A. B. R.
	Catskills	....	100	120	150	200	295	A. B. R.
Yellow Birch........	Mich. & Wis.	....	85	105	135	155	190	U.S.D.A.Bul. 285, Table 7.
	Adirondacks	....	......	......	90	150	190	A. B. R.
	Catskills	....	70	90	120	145	180	A. B. R.
Sugar Maple.........	Mich. & Wis.	....	90	110	140	170	215	U.S.D.A.Bul. 285, Table 7.
	Adirondacks	....	......	......	145	165	190	A. B. R.
	Catskills	....	85	105	135	165	195	A. B. R.
Aspen (Popple)......	Maine	Site I	20	30	45	55	75	U. S. F. S. Bul. 93.
		Site II	30	40	60	85		
		Site III	50	70	95			

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* Graves in his "Principles of Handling Woodlands," Wiley & Sons, Inc., N. Y., 1911, says (p. 12): "In the Adirondacks it requires on an average 180 years for a spruce to reach a diameter of 12 inches. Under favorable conditions, it is possible for spruce to reach 12 inches in from 80 to 100 years."

In New England, second growth stands of spruce on old pastures will reach 6 inches in from 30 to 50 years and 8 inches in from 45 to 90 years, depending on the site. (U. S. D. A. Bul. 544, Table 12.)

Planted stands of Norway spruce will reach 6 inches in 25 years, 8 inches in 35 years, and 11 inches in 55 years. (U. S. D. A. Bul. 544, Table 13.)

TECHNICAL ROTATIONS OF IMPORTANT SPECIES — (*Continued*)

Species.	Locality.		To reach 6-inch d. b. h. (posts), years.	To reach 8-inch d. b. h. (*e.g.* pulp), years.	To reach 11-inch d. b. h. (ties), years.	To reach 14-inch d. b. h. (poles), years.	To reach 18-inch d. b. h. (saw-timber), years.	Authority.
Central Hardwood Forest								
Chestnut.	Md.	. . . .	20	25	40	55	85	U. S. F. S. Bul. 36.
"	Conn.	Site I	30	40	60	. . . .	. . . .	U. S. F. S. Bul. 96, Tables 17–19.
(even-aged sprout stands)	Conn.	Site II	35	50	75	. . . .	. . . .	
	Conn.	Site III	45	60	over 75	. . . .	. . . .	
Oaks: Black.	Ky.	. . . .	25	35	50	. . . .	130	U. S. F. S. Bul. 36, Table 63.
Red.	Ky.	. . . .	25	30	45	. . . .	100	
White.	Ky.	. . . .	35	45	80	. . . .	160	
Mixed.	Conn.	Site I	35	45	70	. . . .	. . . .	U. S. F. S. Bul. 96, Tables 23–25.
(even-aged sprout stands)	Conn.	Site II	40	60	over 75	. . . .	. . . .	
	Conn.	Site III	55–60	over 75	. . . .	. . . .	. . . .	
White Ash.	Ind.	. . . .	60	70	80	. . . .	. . . .	U. S. D. A. Bul. 299, Tables 8 and 9.
	Tenn.	. . . .	50	60	75	95	120	
	N. Y.	Sandy loam to clay soil	25 to 35	35 to 50	50 to 75	65 to 105	. . . .	U. S. D. A. Bul. 299.
Yellow Poplar.	Tenn.	. . . .	. . . .	45	. . . .	. . . .	110	U. S. F. S. Bul. 36, Table 63.
	Va.	2d growth	20	25	. . . .	. . . .	. . . .	
Hickory: Pignut.	Ind. & Ky.	2d growth	55	65	85	. . . .	. . . .	U. S. F. S. Bul. 80, Tables 4 and 6.
Shagbark.	Ind. & Ky.	2d growth	45	60	85	. . . .	. . . .	
Bitternut. . .	Ind. & Ky.	2d growth	30	45	60	80	. . . .	
Pignut.	Ind. & Ky.	Sprouts	35	45	. . . .	. . . .	. . . .	
Shagbark. . .	Ind. & Ky.	Sprouts	30	45	. . . .	. . . .	. . . .	
Mockernut	Miss.	. . . .	50	65	. . . .	. . . .	135	U. S. F. S. Bul. 36, Table 63.

TECHNICAL ROTATIONS OF IMPORTANT SPECIES — (*Continued*)

Species.	Locality.		To reach 6-inch d. b. h. (posts), years.	To reach 8-inch d. b. h. (*e.g.* pulp), years.	To reach 11-inch d. b. h. (ties), years.	To reach 14-inch d. b. h. (poles), years.	To reach 18-inch d. b. h. (saw-timber), years.	Authority.
SOUTHERN FOREST								
Longleaf Pine........	S. C.	....	....	....	75	100	130	U. S. F. S. Bul. 36, Table 63.
	Fla.	....	55	75	120	185	....	Working Plan, Florida National Forest.
Loblolly Pine........	S. C.	....	20	25	40	55	70	U. S. F. S. Bul. 36, Table 63.
	N. C.	Site I	....	25	40	55	85	N. C. Geol. Ec. Survey, Bul. 24, Table 16.
		Site II	....	25 to 30	45	65	over 100	
		Site III	20	35	55	80	....	
	Md.	Site I	20	30	45	....	....	U. S. D. A. Bul. 11, Table 2.
		Site II	20 to 25	35	over 50	....	....	
		Site III	30	50	....	....	....	
	Tex.	Pure stands	15 to 20	20 to 25	25 to 30	30 to 35	45	U. S. F. S. Bul. 64, Table XIII.
		Mixed with hdwds.	20	25	35	45	65	
Short-leaf Pine	Ark.	....	....	55	75	100	130	U. S. F. S. Bul. 36, Table 63.
	W. Ark.	....	20	30	45	70	120	U. S. D. A. Bul. 244, Table 10.
	N. C.	....	20	30	50	over 80	....	"
	N. C.	Site I	20	30	50	70	....	U. S. D. A. Bul. 308, Table 14.
		Site II	25	40	65	over 80	....	
		Site III	35	55	over 80	....	....	
	Ark.	Site I	....	20	35 to 40	60	over 80	U. S. D. A. Bul. 308, Table 16.
		Site II	....	30	45 to 50	75	over 80	
		Site III	....	35	60	over 80	....	
Slash Pine...........	Fla.	Average	20	25	45	....	....	Mattoon in Proc. Soc. Amer. For., Vol. XI, No. 9, p. 409.
		Maximum	10 to 15	15 to 20	25	40	over 50	
		Minimum	30	50	....	....	....	
Southern Cypress....	Md.	2d growth	30	35	50	65	85	U. S. D. A. Bul. 272, Tables 11 and 12.
	La.	....	50	65	90	125	170	

TECHNICAL ROTATIONS OF IMPORTANT SPECIES — (*Continued*)

Species.	Locality.		To reach 6-inch d. b. h. (posts), years.	To reach 8-inch d. b. h. (*e.g.* pulp), years.	To reach 11-inch d. b. h. (ties), years.	To reach 14-inch d. b. h. (poles), years.	To reach 18-inch d. b. h. (saw-timber), years.	Authority.
Rocky Mt. Forest								
Wes. Yellow Pine....	Ariz.	"yellow pine"	45	55 to 60	80	110	160	U. S. F. S. Bul. 101, Tables 9, 10 and 11.
	Ariz.	"black jack"	30	40	55	70	100	
	Ariz. & N. Mex.	....	40	55	75	105	145	
Wes. Yellow Pine....	S. Dak.	....	70	90	130	195	....	U. S. F. S. Circ. 127, Table 12.
	Mont.	....	55	70	100	130	over 200	
	Colo.	....	45	55	75	100	160	
Lodgepole Pine......	Mont.	Dominant Trees	55	80	125	185	over 200	U. S. D. A. Bul. 154, Tables 2 and 3.
	Mont.	Average	85	120	195	over 200	....	
	Wyo.	Bighorn	55	75	130	over 200	....	
	Wyo.	Medicine Bow	85	125	195	over 200	....	
Douglas Fir.........	Ida.	....	50	60	75	90	120	U. S. F. S. Circ. 150, Table p. 30.
	Utah	....	65	75	100	125	170	
	Colo.	....	100	120	155	200	....	
	Ariz.	....	35	40	55	70	100	Crook Nat. For. Working Plan.
Englemann Spruce...	Ariz.	....	60	65	80	90	115	Crook Nat. For. Working Plan.
Utah Juniper........	Ariz.	In open	90	120	170	....	....	U. S. F. S. Circ. 197, Table 5.
Piñon Pine..........	N. Mex.	Piñon	120	170	over 200	....	....	Walter Mulford, 1910.
Rocky Mt. Juniper...	N. Mex.	Juniper type	130	180	over 200	....	....	Walter Mulford, 1910.
Emory Oak..........	So. Ariz.	Injury sprouts	30	40	55	70	90	U. S. F. S. Circ. 201, Table 1.
	So. Ariz.	Stump "	20	25	over 35	....	....	

TECHNICAL ROTATIONS OF IMPORTANT SPECIES — (*Continued*)

Species.	Locality.		To reach 6-inch d. b. h. (posts), years.	To reach 8-inch d. b. h. (*e.g.* pulp), years.	To reach 11-inch d. b. h. (ties), years.	To reach 14-inch d. b. h. (poles), years.	To reach 18-inch d. b. h. (saw-timber), years.	Authority.
PACIFIC COAST FOREST								
Douglas Fir.........	Western Wash.	....	25	30	40	50	70	U. S. F. S. Circ. 150, Table, p. 30.
	Oregon and West. Wash.	Site I	25	35	45	60	80	Hanzlik in For. Quart., Vol. XII, No. 3. Pages 440–451. Tables 1 to 5.
		Site II	30	40	55	70	140	
		Site III	40	50	70	110	....	
		Ave. of all sites	30	40	55	75	110	
Sugar Pine..........	Cal.	....	55	60	70	85	100	U. S. D. A. Bul. 426, Table 17.
	Cal.	....	40	50	65	....	100	U. S. F. S. Bul. 36, Table 63.
Wes. Yellow Pine....	Ore.	....	50	50 to 55	55 to 60	60 to 65	70	U. S. D. A. Bul. 418, Table 10.
	Cal.	....	25	35	45	55	80	U. S. F. S. Bul. 36, Table 63.
	Wash.	....	40	50	70	95	125	U. S. F. S. Circ. 127, Table 12.
Redwood............	Cal.	Sprouts	20	25	35	50	70	U. S. F. S. Bul. 36, Table 63.
White Fir..........	Cal.	....	....	75	....	....	140	U. S. F. S. Bul. 36, Table 63.
Wes. Hemlock.......	Wash.	....	....	50	70	....	125	U. S. F. S. Bul. 36, Table 63.
Wes. White Pine....	Ida.	Site I	20	35	60	90	....	U. S. F. S. Bul. 36, Table 61.
Incense Cedar......	Cal.	....	60	70	85	100	120	U. S. D. A. Bul. 426, Table 19.
Lodgepole Pine.....	Ore.	....	45	60	90	....	....	Univ. of Wash. For. Club Annual, Vol. IV, p. 33, Table 9 — (Hanzlik).

Outline for Forest Description

A. *General* (for the whole tract).

1. *Situation and altitude.* Reference to mountains, ridges, streams, camps, etc. Elevation above sea level, if possible.

2. *Topography.*

(*a*) General character — level, hilly, or mountainous. Percentage of level land and steep slopes.
(*b*) Height of the hills above the local streams.
(*c*) Drainage. Size of streams; navigable or drivable.

3. *Rock.* Outcrops. Quantity and size of boulders.

B. *Specific* (for each forest type).

1. *Slope and aspect* (aspect = exposure).

(*a*) Slope:

Level	0 to 5	per cent	0 to 3	degrees
Gentle	5 to 15	"	3 to 8½	"
Medium	15 to 30	"	8½ to 16½	"
Steep	30 to 50	"	16½ to 26½	"
Very steep	50 to 100	"	26½ to 45	"
Precipitous	over 100	"	over 45	"

(*b*) Aspect:

Eight principal points of the compass. (N, N–E, S, S–E, etc.)

2. *Soil.*

(*a*) Physical composition. (Gravel, sand, loam, clay and intermediate forms.)
(*b*) Depth:

Very shallow = less than 6 inches
Shallow = 6 to 12 "
Moderate = 12 to 24 "
Deep = 24 to 36 "
Very Deep = 36 inches +

(*c*) Color and consistency.
(*d*) Moisture. (Wet, moist, fresh, dry or very dry.)
(*e*) Agricultural value.

3. *Forest floor.* (Vegetable matter on the ground.)
   (*a*) Litter (the upper, only slightly decomposed portion of the forest floor). Deep, moderate, scanty, etc.
   (*b*) Humus (well decomposed). Depth in inches.
4. *Ground cover.* (All small plants, except trees.) Herbaceous, woody, grass, ferns, etc. Give amounts.
5. *Underbrush.* (All large woody plants which are not trees.)
6. *Reproduction.* (Trees less than 10 feet high; from sprouts or from self-sown seeds.) State whether the reproduction is from seeds or from sprouts, and the relative abundance of it.
7. *Stand.* Any special features not apparent from an examination of the tally sheets, should here be mentioned. Density of crown cover, form of trees, and apparent vigor of growth, etc.
8. *Merchantable condition.* Damage by fire, grazing animals, insects, fungi, and atmospheric agents.
9. *Site class.* (Forest-producing power of the locality.) Usually expressed in qualities, as I, II, and III. See Chapter XI.

Outline for a Planting Plan

Prepared by S. N. Spring, Professor of Silviculture at Cornell University.

1. *Title.*
2. *Introduction.*
3. *General description of tract* giving broadly also the purpose and usefulness of planting, mentioning species and stating reasons for choice.
4. *Planting sites* (each designated by a number or letter).
   (*a*) Area.
   (*b*) Description.
   (*c*) Species recommended.
   (*d*) Spacing of trees (make diagram).
   (*e*) Number of trees required (or quantity of seed if direct seeding).
   (*f*) Special instructions.

5. *Summary of recommendations for sites* (*tabular form showing sites, area, species, number of trees*).
6. *Annual plantings.* (A schedule by years to indicate suggested sequence of annual planting operations.)
7. *Source of stock or seed.* (Nursery plan if required.)
8. *Preparation of the sites and preliminary protective measures.*
9. *Planting instructions.* Full details pertaining to methods of planting and local conditions governing the execution of the plan.
10. *Future treatmeat* (*protection, cleanings, etc.*, during first decade).
11. *Financial considerations.*
12. *Appendix — maps and photographs.*

COMPOUND INTEREST TABLES

Note. — These tables are taken from Chapman: " Forest Valuation," John Wiley and Sons, Inc., N. Y., 1915, pp. 249–264. The period of years, *n*, appears in the left-hand column.

Column I, Formula I = Future value of $1 at end of *n* years. (See page 184.)

" II, " II = Present value of $1 due in *n* years. (See page 184.)

" III, " IV = Future value at end of *n* years of an annual rental of $1 payable *n* times. (See page 185.)

Column IV, Formula V = Present value of an annual rental of $1 payable *n* times. (See page 186.)

½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0050	.9950	1.0000	.9950
2	1.0100	.9901	2.0050	1.9851
3	1.0151	.9851	3.0150	2.9702
4	1.0202	.9802	4.0301	3.9505
5	1.0253	.9754	5.0503	4.9259
6	1.0304	.9705	6.0755	5.8964
7	1.0355	.9657	7.1059	6.8621
8	1.0407	.9609	8.1414	7.8230
9	1.0459	.9561	9.1821	8.7791
10	1.0511	.9513	10.2280	9.7304
11	1.0564	.9466	11.2792	10.6770
12	1.0617	.9419	12.3356	11.6189
13	1.0670	.9372	13.3972	12.5562
14	1.0723	.9326	14.4642	13.4887
15	1.0777	.9279	15.5365	14.4166
16	1.0831	.9233	16.6142	15.3399
17	1.0885	.9187	17.6973	16.2586
18	1.0939	.9141	18.7858	17.1728
19	1.0994	.9096	19.8797	18.0824
20	1.1049	.9051	20.9791	18.9874
21	1.1104	.9006	22.0840	19.8880
22	1.1160	.8961	23.1944	20.7841
23	1.1216	.8916	24.3104	21.6756
24	1.1272	.8872	25.4320	22.5629
25	1.1328	.8828	26.5591	23.4456
26	1.1385	.8784	27.6919	24.3240
27	1.1442	.8740	28.8304	25.1980
28	1.1499	.8697	29.9745	26.0677
29	1.1556	.8653	31.1244	26.9330
30	1.1614	.8610	32.2800	27.7941
31	1.1672	.8567	33.4414	28.6508
32	1.1730	.8525	34.6086	29.5033
33	1.1789	.8482	35.7817	30.3515
34	1.1848	.8440	36.9606	31.1955
35	1.1907	.8398	38.1454	32.0354
36	1.1967	.8356	39.3361	32.8710
37	1.2027	.8315	40.5328	33.7025
38	1.2087	.8274	41.7354	34.5299
39	1.2147	.8232	42.9441	35.3531
40	1.2208	.8191	44.1588	36.1722
41	1.2269	.8151	45.3796	36.9873
42	1.2330	.8110	46.6065	37.7983
43	1.2392	.8070	47.8306	38.6053
44	1.2454	.8030	49.0788	39.4082
45	1.2516	.7990	50.3242	40.2072
46	1.2579	.7950	51.5758	41.0022
47	1.2642	.7910	52.8337	41.7932
48	1.2705	.7871	54.0978	42.5803
49	1.2768	.7832	55.3683	43.3635
50	1.2832	.7793	56.6452	44.1428
55	1.3156	.7601	63.1200	47.9782
60	1.3488	.7414	69.7600	51.7020
65	1.3829	.7231	76.5800	55.2764
70	1.4178	.7053	83.5600	58.9364
75	1.4536	.6879	90.7200	62.4745
80	1.4903	.6710	98.0600	65.7988
85	1.5280	.6545	105.6009	69.1099
90	1.5665	.6383	113.3000	72.3268
95	1.6061	.6226	121.2200	75.4747
100	1.6467	.6073	129.3400	78.5449
105	1.6882	.5923	137.6400	81.5306
100	1.7309	.5777	146.1800	84.4531
115	1.7746	.5635	154.9200	87.2985
120	1.8194	.5496	163.8800	90.0736

1 PER CENT

n years.	I.	II.	III.	IV.
1	1.0100	.9901	1.0000	.9901
2	1.0201	.9803	2.0100	1.9704
3	1.0303	.9706	3.0301	2.9410
4	1.0406	.9610	4.0604	3.9020
5	1.0510	.9515	5.1010	4.8534
6	1.0615	.9420	6.1520	5.7955
7	1.0721	.9327	7.2135	6.7282
8	1.0829	.9235	8.2857	7.6517
9	1.0937	.9143	9.3685	8.5660
10	1.1046	.9053	10.4622	9.4713
11	1.1157	.8963	11.5668	10.3676
12	1.1268	.8874	12.6825	11.2551
13	1.1381	.8787	13.8093	12.1337
14	1.1495	.8700	14.9474	13.0037
15	1.1610	.8613	16.0969	13.8651
16	1.1726	.8528	17.2579	14.7179
17	1.1843	.8444	18.4304	15.5622
18	1.1961	.8360	19.6147	16.3983
19	1.2081	.8277	20.8109	17.2260
20	1.2202	.8195	22.0190	18.0456
21	1.2324	.8114	23.2392	18.8570
22	1.2447	.8034	24.4716	19.6604
23	1.2572	.7954	25.7163	20.4558
24	1.2697	.7876	26.9735	21.2434
25	1.2824	.7798	28.2432	22.0232
26	1.2953	.7720	29.5256	22.7952
27	1.3082	.7644	30.8209	23.5596
28	1.3213	.7568	32.1291	24.3164
29	1.3345	.7493	33.4504	25.0658
30	1.3478	.7419	34.7849	25.8077
31	1.3613	.7346	36.1327	26.5423
32	1.3749	.7273	37.4941	27.2696
33	1.3887	.7201	38.8690	27.9897
34	1.4026	.7130	40.2577	28.7027
35	1.4166	.7059	41.6603	29.4086
36	1.4308	.6989	43.0769	30.1075
37	1.4451	.6920	44.5076	30.7995
38	1.4595	.6852	45.9527	31.4847
39	1.4741	.6784	47.4123	32.1630
40	1.4889	.6717	48.8864	32.8347
41	1.5038	.6650	50.3752	33.4997
42	1.5188	.6584	51.8790	34.1581
43	1.5340	.6519	53.3978	34.8100
44	1.5493	.6454	54.9318	35.4554
45	1.5648	.6391	56.4811	36.0945
46	1.5805	.6327	58.0459	36.7272
47	1.5963	.6265	59.6263	37.3537
48	1.6122	.6203	61.2226	37.9740
49	1.6283	.6141	62.8348	38.5881
50	1.6446	.6080	64.4632	39.1961
55	1.7284	.5786	72.8400	42.1430
60	1.8166	.5505	81.6600	44.9521
65	1.9093	.5238	90.9300	47.6247
70	2.0066	.4983	100.6600	50.1644
75	2.1090	.4742	110.9000	52.5841
80	2.2166	.4500	121.6600	54.8858
85	2.3296	.4292	132.9600	57.0742
90	2.4485	.4084	144.8500	59.1750
95	2.5733	.3886	157.3300	61.1394
100	2.7046	.3697	170.4600	63.0259
105	2.8425	.3518	184.2500	64.8197
110	2.9875	.3347	198.7500	66.5272
115	3.1399	.3185	213.9900	68.1518
120	3.3001	.3030	230.0100	69.6979

1½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0150	.9852	1.0000	.9852
2	1.0302	.9707	2.0150	1.9559
3	1.0457	.9563	3.0452	2.9122
4	1.0614	.9422	4.0909	3.8544
5	1.0773	.9283	5.1523	4.7826
6	1.0934	.9145	6.2290	5.6972
7	1.1098	.9010	7.3230	6.5982
8	1.1265	.8877	8.4328	7.4859
9	1.1434	.8746	9.5593	8.3605
10	1.1605	.8617	10.9027	9.2222
11	1.1779	.8489	11.8633	10.0711
12	1.1959	.8364	13.0412	10.9075
13	1.2130	.8240	14.2368	11.7315
14	1.2318	.8118	15.4504	12.5434
15	1.2502	.7999	16.6821	13.3432
16	1.2690	.7880	17.9324	14.1313
17	1.2880	.7764	19.2014	14.9076
18	1.3073	.7649	20.4894	15.6726
19	1.3270	.7536	21.7967	16.4262
20	1.3469	.7425	23.1237	17.1686
21	1.3671	.7315	24.4705	17.9001
22	1.3876	.7207	25.8376	18.6208
23	1.4084	.7100	27.2251	19.3309
24	1.4295	.6995	28.6335	20.0304
25	1.4509	.6892	30.0630	20.7196
26	1.4727	.6790	31.5140	21.3986
27	1.4948	.6690	32.9867	22.0676
28	1.5172	.6591	34.4815	22.7267
29	1.5400	.6494	35.9987	23.3761
30	1.5631	.6398	37.5387	24.0158
31	1.5865	.6303	39.1018	24.6461
32	1.6103	.6210	40.6883	25.2671
33	1.6345	.6118	42.2986	25.8790
34	1.6590	.6028	43.9331	26.4817
35	1.6839	.5939	45.5921	27.0756
36	1.7091	.5851	47.2760	27.6607
37	1.7348	.5764	48.9851	28.2371
38	1.7608	.5679	50.7199	28.8051
39	1.7872	.5595	52.4807	29.3646
40	1.8140	.5513	54.2679	29.9158
41	1.8412	.5431	56.0819	30.4590
42	1.8688	.5351	57.9231	30.9940
43	1.8969	.5272	59.7920	31.5212
44	1.9253	.5194	61.6889	32.0406
45	1.9542	.5117	63.6142	32.5523
46	1.9835	.5042	65.5684	33.0565
47	2.0133	.4967	67.5519	33.5532
48	2.0435	.4894	69.5652	34.0426
49	2.0741	.4821	71.6087	34.5247
50	2.1052	.4750	73.6828	34.9997
55	2.2679	.4409	84.5296	37.2715
60	2.4432	.4093	96.2147	39.3803
65	2.6320	.3799	108.8000	41.3373
70	2.8355	.3527	122.3640	43.1549
75	3.0546	.3274	136.9670	44.8409
80	3.2907	.3039	152.7110	46.4073
85	3.5450	.2821	169.6600	47.8603
90	3.8189	.2618	187.9300	49.2099
95	4.1141	.2431	207.6000	50.4618
100	4.4320	.2256	228.8030	51.6247
105	4.7746	.2094	251.6330	52.7036
110	5.1436	.1944	276.2380	53.7055
115	5.5411	.1805	302.7330	54.6351
120	5.9693	.1675	331.2880	55.4985

2 PER CENT

n years.	I.	II.	III.	IV.
1	1.0200	.9804	1.0000	.9804
2	1.0404	.9612	2.0200	1.9416
3	1.0612	.9423	3.0604	2.8839
4	1.0824	.9238	4.1216	3.8077
5	1.1041	.9056	5.2040	4.7135
6	1.1262	.8880	6.3081	5.6014
7	1.1487	.8706	7.4343	6.4720
8	1.1717	.8535	8.5830	7.3255
9	1.1951	.8368	9.7546	8.1622
10	1.2190	.8203	10.9497	8.9826
11	1.2434	.8043	12.1687	9.7868
12	1.2682	.7885	13.4121	10.5753
13	1.2936	.7730	14.6803	11.3484
14	1.3195	.7579	15.9739	12.1062
15	1.3459	.7430	17.2934	12.8493
16	1.3728	.7284	18.6393	13.5777
17	1.4002	.7142	20.0121	14.2919
18	1.4282	.7002	21.4123	14.9920
19	1.4568	.6864	22.8406	15.6785
20	1.4859	.6730	24.2974	16.3514
21	1.5157	.6598	25.7833	17.0112
22	1.5460	.6468	27.2990	17.6580
23	1.5769	.6342	28.8450	18.2922
24	1.6084	.6217	30.4219	18.9139
25	1.6406	.6095	32.0303	19.5235
26	1.6734	.5976	33.6709	20.1210
27	1.7069	.5859	35.3443	20.7069
28	1.7410	.5744	37.0512	21.2813
29	1.7758	.5631	38.7922	21.8444
30	1.8114	.5521	40.5681	22.3965
31	1.8476	.5412	42.3794	22.9377
32	1.8845	.5306	44.2270	23.4683
33	1.9222	.5202	46.1116	23.9886
34	1.9607	.5100	48.0338	24.4986
35	1.9999	.5000	49.9945	24.9986
36	2.0399	.4902	51.9944	25.4888
37	2.0807	.4806	54.0343	25.9695
38	2.1223	.4712	56.1149	26.4406
39	2.1647	.4619	58.2372	26.9026
40	2.2080	.4529	60.4020	27.3555
41	2.2522	.4440	62.6100	27.7995
42	2.2972	.4353	64.8622	28.2348
43	2.3432	.4268	67.1595	28.6616
44	2.3901	.4184	69.5027	29.0800
45	2.4379	.4102	71.8927	29.4902
46	2.4866	.4022	74.3306	29.8923
47	2.5363	.3943	76.8172	30.2866
48	2.5871	.3865	79.3535	30.6731
49	2.6388	.3790	81.9406	31.0521
50	2.6916	.3715	84.5794	31.4236
55	2.9717	.3365	98.5865	33.1748
60	3.2810	.3048	114.0520	34.7609
65	3.6225	.2760	131.1250	36.1973
70	3.9995	.2500	149.9780	37.4986
75	4.4158	.2265	170.7900	38.6763
80	4.8754	.2051	193.7720	39.7445
55	5.3828	.1858	219.1400	40.7111
90	5.9431	.1683	247.1570	41.5869
95	6.5617	.1524	278.0850	42.3800
100	7.2446	.1380	312.2320	43.0984
105	7.9987	.1250	349.9300	43.7489
110	8.8312	.1132	391.5590	44.3382
115	9.7503	.1026	437.5150	44.8719
120	10.7652	.0929	488.2580	45.3554

2½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0250	.9756	1.0000	.9756
2	1.0506	.9518	2.0250	1.9274
3	1.0769	.9286	3.0756	2.8560
4	1.1038	.9060	4.1525	3.7620
5	1.1314	.8839	5.2563	4.6458
6	1.1597	.8623	6.3877	5.5081
7	1.1887	.8413	7.5474	6.3494
8	1.2184	.8207	8.7361	7.1701
9	1.2489	.8007	9.9545	7.9709
10	1.2801	.7812	11.2034	8.7521
11	1.3121	.7621	12.4835	9.5142
12	1.3449	.7436	13.7956	10.2578
13	1.3785	.7254	15.1404	10.9832
14	1.4130	.7077	16.5190	11.6909
15	1.4483	.6905	17.9319	12.3814
16	1.4845	.6736	19.3802	13.0550
17	1.5216	.6572	20.8647	13.7122
18	1.5597	.6412	22.3863	14.3534
19	1.5987	.6255	23.9460	14.9789
20	1.6386	.6103	25.5447	15.5892
21	1.6796	.5954	27.1833	16.1845
22	1.7216	.5809	28.8629	16.7654
23	1.7646	.5667	30.5844	17.3321
24	1.8087	.5529	32.3490	17.8850
25	1.8539	.5394	34.1578	18.4244
26	1.9003	.5262	36.0117	18.9506
27	1.9478	.5134	37.9120	19.4640
28	1.9965	.5009	39.8598	19.9649
29	2.0464	.4887	41.8563	20.4535
30	2.0976	.4767	43.9027	20.9303
31	2.1500	.4651	46.0003	21.3954
32	2.2038	.4538	48.1503	21.8492
33	2.2589	.4427	50.3540	22.2919
34	2.3153	.4319	52.6129	22.7238
35	2.3732	.4214	54.9282	23.1452
36	2.4325	.4111	57.3014	23.5563
37	2.4933	.4011	59.7339	23.9573
38	2.5557	.3913	62.2273	24.3486
39	2.6196	.3817	64.7830	24.7303
40	2.6851	.3724	67.4026	25.1028
41	2.7522	.3633	70.0876	25.4661
42	2.8210	.3545	72.8398	25.8206
43	2.8915	.3458	75.6608	26.1664
44	2.9638	.3374	78.5523	26.5038
45	3.0379	.3292	81.5161	26.8330
46	3.1139	.3211	84.5540	27.1542
47	3.1917	.3133	87.6679	27.4675
48	3.2715	.3057	90.8596	27.7732
49	3.3533	.2982	94.1311	28.0714
50	3.4371	.2909	97.4843	28.3623
55	3.8888	.2571	115.551	29.7140
60	4.3998	.2273	135.992	30.9087
65	4.9780	.2009	159.120	31.963
70	5.6321	.1775	185.284	32.898
75	6.3722	.1569	214.888	33.645
80	7.2096	.1387	248.383	34.452
85	8.1570	.1226	286.280	35.096
90	9.2289	.1084	329.154	35.666
95	10.4416	.0958	377.664	36.171
100	11.8137	.0846	432.549	36.614
105	13.3661	.0748	494.644	37.007
110	15.1226	.0661	564.902	37.355
115	17.1098	.0584	644.392	37.664
120	19.3581	.0517	734.326	37.934

3 PER CENT

n years.	I.	II.	III.	IV.
1	1.0300	.9709	1.0000	.9709
2	1.0609	.9426	2.0300	1.9135
3	1.0927	.9151	3.0909	2.8286
4	1.1255	.8885	4.1836	3.7171
5	1.1593	.8626	5.3091	4.5797
6	1.1941	.8375	6.4684	5.4172
7	1.2299	.8131	7.6625	6.2303
8	1.2668	.7894	8.8923	7.0197
9	1.3048	.7664	10.1591	7.7861
10	1.3439	.7441	11.4639	8.5302
11	1.3842	.7224	12.8075	9.2526
12	1.4258	.7014	14.1920	9.9540
13	1.4685	.6810	15.6178	10.6350
14	1.5126	.6611	17.0863	11.2961
15	1.5580	.6419	18.5989	11.9379
16	1.6047	.6232	20.1569	12.5611
17	1.6528	.6050	21.7616	13.1661
18	1.7024	.5874	23.4144	13.7535
19	1.7535	.5703	25.1169	14.3238
20	1.8061	.5537	26.8704	14.8775
21	1.8603	.5375	28.6765	15.4150
22	1.9161	.5219	30.5368	15.9369
23	1.9736	.5067	32.4529	16.4436
24	2.0328	.4919	34.4265	16.9325
25	2.0938	.4776	36.4593	17.4131
26	2.1566	.4637	38.5530	17.8768
27	2.2213	.4502	40.7096	18.3270
28	2.2879	.4371	42.9309	18.7641
29	2.3566	.4243	45.2189	19.1885
30	2.4273	.4120	47.5754	19.6004
31	2.5001	.4000	50.0027	20.0004
32	2.5751	.3883	52.5028	20.3888
33	2.6523	.3770	55.0778	20.7658
34	2.7319	.3660	57.7302	21.1318
35	2.8139	.3554	60.4621	21.4872
36	2.8983	.3450	63.2759	21.8323
37	2.9852	.3350	66.1742	22.1672
38	3.0748	.3252	69.1594	22.4925
39	3.1670	.3158	72.2342	22.8082
40	3.2620	.3066	75.4013	23.1148
41	3.3599	.2976	78.6633	23.4124
42	3.4607	.2890	82.0232	23.7014
43	3.5645	.2805	85.4839	23.9819
44	3.6715	.2724	89.0484	24.2543
45	3.7816	.2644	92.7199	24.5187
46	3.8950	.2567	96.5015	24.7754
47	4.0119	.2493	100.3965	25.0247
48	4.1323	.2420	104.4084	25.2667
49	4.2562	.2350	108.5406	25.5017
50	4.3839	.2281	112.7969	25.7298
55	5.0821	.1968	136.072	26.7744
60	5.8916	.1697	163.053	27.6756
65	6.8300	.1464	194.333	28.452
70	7.9178	.1263	230.594	29.123
75	9.1789	.1089	272.630	29.702
80	10.6409	.0940	321.363	30.201
85	12.3357	.0811	377.857	30.701
90	14.3005	.0699	443.349	31.002
95	16.5782	.0603	519.273	31.323
100	19.2186	.0520	607.288	31.599
105	22.2797	.0449	709.323	31.838
110	25.8282	.0387	827.608	32.043
115	29.9420	.0334	964.733	32.220
120	34.7110	.0288	1123.70	32.373

3½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0350	.9662	1.0000	.9662
2	1.0712	.9335	2.0350	1.8997
3	1.1087	.9019	3.1062	2.8016
4	1.1475	.8714	4.2149	3.6731
5	1.1877	.8420	5.3625	4.5151
6	1.2293	.8135	6.5502	5.3286
7	1.2723	.7860	7.7794	6.1145
8	1.3168	.7594	9.0517	6.8740
9	1.3629	.7337	10.3685	7.6077
10	1.4106	.7089	11.7314	8.3166
11	1.4600	.6849	13.1420	9.0016
12	1.5111	.6618	14.6020	9.6633
13	1.5640	.6394	16.1130	10.3027
14	1.6187	.6178	17.6770	10.9205
15	1.6753	.5969	19.2957	11.5174
16	1.7340	.5767	20.9710	12.0941
17	1.7947	.5572	22.7050	12.6513
18	1.8575	.5384	24.4997	13.1897
19	1.9225	.5202	26.3572	13.7098
20	1.9898	.5026	28.2797	14.2124
21	2.0594	.4856	30.2695	14.6980
22	2.1315	.4692	32.3289	15.1671
23	2.2061	.4533	34.4604	15.6204
24	2.2833	.4380	36.6665	16.0574
25	2.3632	.4231	38.9499	16.4815
26	2.4460	.4088	41.3131	16.8904
27	2.5316	.3950	43.7591	17.2854
28	2.6202	.3817	46.2906	17.6670
29	2.7119	.3687	48.9108	18.0358
30	2.8068	.3563	51.6227	18.3920
31	2.9050	.3442	54.4295	18.7363
32	3.0067	.3326	57.3345	19.0689
33	3.1119	.3213	60.3412	19.3902
34	3.2209	.3105	63.4532	19.7007
35	3.3336	.3000	66.6740	20.0007
36	3.4503	.2898	70.0076	20.2905
37	3.5710	.2800	73.4579	20.5705
38	3.6960	.2706	77.0289	20.8411
39	3.8254	.2614	80.7249	21.1025
40	3.9593	.2526	84.5503	21.3551
41	4.0978	.2440	88.5095	21.5991
42	4.2413	.2358	92.6074	21.8349
43	4.3897	.2278	96.8487	22.0627
44	4.5433	.2201	101.2383	22.2828
45	4.7024	.2127	105.7817	22.4955
46	4.8669	.2055	110.4840	22.7009
47	5.0373	.1985	115.3510	22.8994
48	5.2136	.1918	120.3883	23.0912
49	5.3961	.1853	125.6018	23.2766
50	5.5849	.1791	130.9979	23.4556
55	6.6331	.1508	160.947	24.2641
60	7.8781	.1269	196.517	24.9447
65	9.3567	.1069	238.763	25.5168
70	11.1128	.0900	288.938	26.0004
75	13.1986	.0758	348.531	26.4067
80	15.6757	.0638	419.307	26.7488
85	18.6179	.0537	503.368	27.0368
90	22.1122	.0452	603.205	27.2793
95	26.2623	.0381	721.780	27.4798
100	31.1914	.0321	862.612	27.6554
105	37.0456	.0270	1029.874	27.8002
110	43.9986	.0227	1228.53	27.9221
115	52.2565	.0191	1464.471	28.0247
120	62.0643	.0161	1744.69	28.1111

4 PER CENT

n years.	I.	II.	III.	IV.
1	1.0400	.9615	1.0000	.9615
2	1.0861	.9246	2.0400	1.8861
3	1.1249	.8890	3.1216	2.7751
4	1.1699	.8548	4.2465	3.6299
5	1.2167	.8219	5.4163	4.4518
6	1.2653	.7903	6.6330	5.2421
7	1.3159	.7599	7.8983	6.0021
8	1.3686	.7307	9.2142	6.7327
9	1.4233	.7026	10.5828	7.4353
10	1.4802	.6756	12.0061	8.1109
11	1.5395	.6496	13.4864	8.7605
12	1.6010	.6246	15.0258	9.3851
13	1.6651	.6006	16.6268	9.9856
14	1.7315	.5775	18.2919	10.5631
15	1.8009	.5553	20.0236	11.1184
16	1.8730	.5339	21.8245	11.6523
17	1.9479	.5134	23.6975	12.1657
18	2.0258	.4936	25.6454	12.6593
19	2.1068	.4746	27.6712	13.1339
20	2.1911	.4564	29.7781	13.5903
21	2.2788	.4388	31.9692	14.0292
22	2.3699	.4220	34.2480	14.4511
23	2.4647	.4057	36.6179	14.8568
24	2.5633	.3901	39.0826	15.2470
25	2.6658	.3751	41.6459	15.6221
26	2.7725	.3607	44.3117	15.9828
27	2.8834	.3468	47.0842	16.3296
28	2.9987	.3335	49.9676	16.6631
29	3.1187	.3207	52.9663	16.9837
30	3.2434	.3083	56.0849	17.2920
31	3.3731	.2965	59.3283	17.5885
32	3.5081	.2851	62.7015	17.8736
33	3.6484	.2741	66.2095	18.1476
34	3.7943	.2636	69.8579	18.4112
35	3.9461	.2534	73.6522	18.6646
36	4.1039	.2437	77.5983	18.9083
37	4.2681	.2343	81.7022	19.1426
38	4.4388	.2253	85.7903	19.3679
39	4.6164	.2166	90.4091	19.5845
40	4.8010	.2083	95.0255	19.7928
41	4.9931	.2003	99.8265	19.9931
42	5.1928	.1926	104.8200	20.1856
43	5.4005	.1852	110.0124	20.3708
44	5.6165	.1780	115.4129	20.5488
45	5.8412	.1712	121.0294	20.7200
46	6.0748	.1646	126.8706	20.8847
47	6.3178	.1583	132.9454	21.0429
48	6.5705	.1522	139.2632	21.1951
49	6.8333	.1463	145.8337	21.3415
50	7.1067	.1407	152.6671	21.4822
55	8.6464	.1157	191.159	22.1086
60	10.5196	.0951	237.991	22.6235
65	12.7987	.0781	294.967	23.0466
70	15.5716	.0642	364.290	23.3945
75	18.9453	.0528	448.642	23.6281
80	23.0498	.0434	551.245	23.9154
85	28.0436	.0357	676.090	24.1085
90	34.1193	.0293	827.983	24.2673
95	41.5114	.0241	1012.785	24.3977
100	50.5049	.0198	1237.622	24.5050
105	61.4470	.0163	1511.175	24.5931
110	74.7597	.0134	1843.992	24.6656
115	90.9566	.0110	2248.915	24.7251
120	110.663	.0090	2741.558	24.7741

4½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0450	.9569	1.0000	.9569
2	1.0920	.9157	2.0450	1.8727
3	1.1412	.8765	3.1370	2.7490
4	1.1925	.8386	4.2782	3.5875
5	1.2462	.8022	5.4707	4.3900
6	1.3023	.7679	6.7169	5.1579
7	1.3609	.7348	8.0192	5.8927
8	1.4221	.7032	9.3800	6.5959
9	1.4861	.6729	10.8021	7.2688
10	1.5530	.6439	12.2882	7.9125
11	1.6229	.6162	13.8412	8.5289
12	1.6959	.4897	15.4640	9.1186
13	1.7722	.5643	17.1599	9.6829
14	1.8519	.5400	18.9321	10.2229
15	1.9353	.5167	20.7841	10.7395
16	2.0224	.4945	22.7193	11.2340
17	2.1134	.4732	24.7417	11.7072
18	2.2085	.4528	26.8551	12.1600
19	2.3079	.4333	29.0634	12.5933
20	2.4117	.4146	31.3716	13.0079
21	2.5202	.3968	33.7831	13.4047
22	2.6337	.3797	36.3034	13.7844
23	2.7522	.3634	38.9370	14.1478
24	2.8760	.3477	41.6892	14.4955
25	3.0054	.3327	44.5652	14.8282
26	3.1407	.3184	47.5706	15.1466
27	3.2820	.3047	50.7113	15.4513
28	3.4279	.2916	53.9933	15.7429
29	3.5840	.2790	57.4230	16.0219
30	3.7453	.2670	61.0071	16.2889
31	3.9139	.2555	64.7524	16.5444
32	4.0900	.2445	68.6662	16.7889
33	4.2740	.2340	72.7562	17.0229
34	4.4664	.2239	77.0303	17.2468
35	4.6673	.2143	81.4966	17.4610
36	4.8774	.2050	86.1640	17.6660
37	5.0969	.1962	91.0413	17.8622
38	5.3262	.1878	96.1382	18.0500
39	5.5659	.1797	101.4644	18.2297
40	5.8164	.1719	107.0303	18.4016
41	6.0781	.1645	112.8467	18.5661
42	6.3516	.1574	118.9248	18.7235
43	6.6374	.1507	125.2764	18.8742
44	6.9361	.1442	131.9138	19.0184
45	7.2482	.1380	138.8500	19.1563
46	7.5744	.1320	146.0982	19.2884
47	7.9153	.1263	153.6726	19.4147
48	8.2715	.1209	161.5879	19.5356
49	8.6437	.1157	169.8594	19.6513
50	9.0326	.1107	178.5030	19.7620
55	11.2563	.0888	227.9180	20.2480
60	14.0274	.0713	289.4980	20.6380
65	17.4807	.0572	366.2380	20.9509
70	21.7841	.0459	461.8700	21.2021
75	27.1470	.0368	581.2670	21.4118
80	33.8301	.0296	729.5580	21.5653
85	42.1585	.0237	914.6330	21.6951
90	52.5371	.0190	1145.2700	21.7992
95	65.4708	.0153	1432.6840	21.8828
100	81.5885	.0123	1790.8600	21.9499
105	101.674	.0098	2237.2000	22.0036
110	126.704	.0079	2793.4300	22.0468
115	157.897	.0063	3486.6000	22.0815
120	196.768	.0051	4350.4000	22.1093

5 PER CENT

n years.	I.	II.	III.	IV.
1	1.0500	.9524	1.0000	.9524
2	1.1025	.9070	2.0500	1.8594
3	1.1576	.8638	3.1525	2.7232
4	1.2155	.8227	4.3101	3.5460
5	1.2763	.7835	5.5256	4.3295
6	1.3401	.7462	6.8019	5.0757
7	1.4071	.7107	8.1420	5.7864
8	1.4775	.6768	9.5491	6.4632
9	1.5513	.6446	11.0266	7.1078
10	1.6289	.6139	12.5779	7.7217
11	1.7103	.5847	14.2068	8.3064
12	1.7959	.5568	15.9171	8.8623
13	1.8856	.5303	17.7130	9.3936
14	1.9799	.5051	19.5986	9.8986
15	2.0789	.4810	21.5786	10.3797
16	2.1829	.4581	23.6575	10.8378
17	2.2920	.4363	25.8404	11.2741
18	2.4066	.4155	28.1324	11.6896
19	2.5270	.3957	30.5390	12.0853
20	2.6533	.3769	33.0660	12.4622
21	2.7860	.3589	35.7193	12.8212
22	2.9253	.3418	38.5052	13.1630
23	3.0715	.3256	41.4305	13.4886
24	3.2251	.3101	44.5020	13.7986
25	3.3864	.2953	47.7271	14.0939
26	3.5557	.2812	51.1135	14.3752
27	3.7335	.2678	54.6691	14.6430
28	3.9201	.2551	58.4026	14.8981
29	4.1161	.2429	62.3227	15.1411
30	4.3219	.2314	66.4388	15.3725
31	4.5380	.2204	70.7608	15.5928
32	4.7649	.2099	75.2988	15.8027
33	5.0032	.1999	80.0638	16.0025
34	5.2533	.1904	85.0670	16.1929
35	5.5160	.1813	90.3203	16.3742
36	5.7918	.1727	95.8363	16.5469
37	6.0814	.1644	101.6281	16.7113
38	6.3855	.1566	107.7095	16.8679
39	6.7048	.1491	114.0950	17.0170
40	7.0400	.1420	120.7998	17.1591
41	7.3920	.1353	127.8398	17.2944
42	7.7616	.1288	135.2318	17.4232
43	8.1497	.1227	142.9933	17.5459
44	8.5572	.1169	151.1430	17.6628
45	8.9850	.1113	159.7002	17.7741
46	9.4343	.1060	168.6852	17.8801
47	9.9060	.1009	178.1194	17.9810
48	10.4013	.0961	188.0254	18.0772
49	10.9213	.0916	198.4267	18.1687
50	11.4674	.0872	209.3480	18.2559
55	14.6356	.0683	272.7130	18.6335
60	18.6792	.0535	353.5840	18.9293
65	23.8399	.0419	456.7980	19.1191
70	30.4264	.0329	588.5290	19.3427
75	38.8327	.0257	756.6540	19.4849
80	49.5614	.0202	971.2290	19.5965
85	63.2544	.0158	1245.0880	19.6838
90	80.7304	.0124	1594.6100	19.7523
95	103.035	.0097	2040.7000	19.8058
100	131.501	.0076	2610.0300	19.8479
105	167.833	.0060	3336.6600	19.8808
110	214.202	.0047	4264.0300	19.9066
115	273.382	.0037	5447.6400	19.9268
120	348.912	.0029	6958.2400	19.9427

5½ PER CENT

n years.	I.	II.	III.	IV.
1	1.0550	.9479	1.0000	.9479
2	1.1130	.8985	2.0550	1.8463
3	1.1742	.8516	3.1680	2.6979
4	1.2388	.8072	4.3423	3.5052
5	1.3070	.7651	5.5811	4.2703
6	1.3788	.7252	6.8881	4.9955
7	1.4547	.6854	8.2669	5.6830
8	1.5347	.6516	9.7216	6.3346
9	1.6191	.6176	11.2563	6.9522
10	1.7081	.5854	12.8754	7.5376
11	1.8021	.5549	14.5835	8.0925
12	1.9012	.5260	16.3856	8.6185
13	2.0058	.4986	18.2868	9.1171
14	2.1161	.4726	20.2926	9.5896
15	2.2325	.4479	22.4087	10.0376
16	2.3553	.4246	24.6411	10.4622
17	2.4848	.4024	26.9964	10.8646
18	2.6215	.3815	29.4812	11.2461
19	2.7656	.3616	32.1027	11.6077
20	2.9178	.3427	34.8683	11.9504
21	3.0782	.3249	37.7861	12.2752
22	3.2275	.3079	40.8643	12.5832
23	3.4262	.2919	44.1118	12.8750
24	3.6146	.2767	47.5380	13.1517
25	3.8134	.2622	51.1526	13.4139
26	4.0231	.2486	54.9660	13.6625
27	4.2444	.2356	58.9891	13.8981
28	4.4778	.2233	63.2335	14.1214
29	4.7241	.2117	67.7114	14.3331
30	4.9840	.2006	71.4355	14.5337
31	5.2581	.1902	77.4194	14.7239
32	5.5473	.1803	82.6775	14.9042
33	5.8524	.1709	88.2248	15.0751
34	6.1742	.1620	94.0771	15.2370
35	6.5138	.1535	100.2514	15.3906
36	6.8721	.1455	106.7652	15.5361
37	7.2501	.1379	113.6373	15.6740
38	7.6488	.1307	120.8873	15.8047
39	8.0695	.1239	128.5361	15.9287
40	8.5133	.1175	136.6056	16.0461
41	8.9815	.1113	145.1189	16.1575
42	9.4755	.1055	154.1005	16.2630
43	9.9967	.1000	163.5760	16.3630
44	10.5465	.0948	173.5727	16.4579
45	11.1266	.0899	184.1192	16.5477
46	11.7385	.0852	195.2457	16.6329
47	12.3841	.0807	206.9842	16.7137
48	13.0653	.0765	219.3684	16.7902
49	13.7838	.0725	232.4336	16.8628
50	14.5420	.0688	246.2175	16.9315
55	19.0046	.0526	327.3563	17.2251
60	24.8381	.0403	433.4200	17.4498
65	32.4623	.0308	572.0364	17.6216
70	43.4150	.0230	771.1818	17.7630
75	56.7414	.0176	1,013.4800	17.8614
80	72.4703	.0138	1,299.4600	17.9309
85	94.7152	.0106	1,703.9127	17.9898
90	123.7883	.0081	2,232.5145	18.0349
95	161.7855	.0062	2,923.3727	18.0694
100	211.4463	.0047	3,826.2963	18.0958
105	276.3503	.0036	5,006.3691	18.1160
110	361.2768	.0028	6,550.4873	18.1315
115	472.0413	.0021	8,564.3873	18.1433
120	616.9357	.0016	11,198.8309	18.1523

6 PER CENT

n years.	I.	II.	III.	IV.
1	1.0600	.9434	1.0000	.9434
2	1.1236	.8900	2.0600	1.8334
3	1.1910	.8396	3.1836	2.6730
4	1.2625	.7921	4.3746	3.4651
5	1.3382	.7473	5.6371	4.2124
6	1.4185	.7050	6.9753	4.9173
7	1.5036	.6651	8.3938	5.5824
8	1.5938	.6274	9.8975	6.2098
9	1.6895	.5919	11.4913	6.8017
10	1.7908	.5584	13.1808	7.3601
11	1.8983	.5268	14.9716	7.8869
12	2.0122	.4970	16.8699	8.3838
13	2.1329	.4688	18.8821	8.8527
14	2.2609	.4423	21.0151	9.2950
15	2.3966	.4173	23.2760	9.7122
16	2.5404	.3936	25.6725	10.1059
17	2.6928	.3714	28.2129	10.4772
18	2.8543	.3503	30.9057	10.8276
19	3.0256	.3305	33.7600	11.1581
20	3.2071	.3118	36.7856	11.4699
21	3.3996	.2942	39.9927	11.7641
22	3.6035	.2775	43.3923	12.0416
23	3.8197	.2618	46.9958	12.3034
24	4.0489	.2470	50.8156	12.5504
25	4.2919	.2330	54.8645	12.7834
26	4.5494	.2198	59.1564	13.0032
27	4.8223	.2074	63.7058	13.2105
28	5.1117	.1956	68.5281	13.4062
29	5.4184	.1846	73.6398	13.5907
30	5.7435	.1741	79.0582	13.7648
31	6.0881	.1643	84.8017	13.9291
32	6.4534	.1550	90.8898	14.0840
33	6.8406	.1462	97.3432	14.2302
34	7.2510	.1379	104.1838	14.3681
35	7.6861	.1301	111.4348	14.4982
36	8.1473	.1227	119.1209	14.6210
37	8.6361	.1158	127.2681	14.7368
38	9.1543	.1092	135.9042	14.8460
39	9.7035	.1031	145.0585	14.9491
40	10.2857	.0972	154.7620	15.0463
41	10.9029	.0917	165.0477	15.1380
42	11.5570	.0865	175.9505	15.2245
43	12.2505	.0816	187.5076	15.3062
44	12.9855	.0770	199.7580	15.3832
45	13.7646	.0727	212.7435	15.4558
46	14.5905	.0685	226.5081	15.5244
47	15.4659	.0647	241.0985	15.5890
48	16.3939	.0610	256.5645	15.6500
49	17.3775	.0575	272.9584	15.7076
50	18.4202	.0543	290.3359	15.7619
55	24.6507	.0406	394.1783	15.9905
60	32.9883	.0303	533.1383	16.1611
65	44.1458	.0226	719.0966	16.2891
70	59.0772	.0169	967.9533	16.3845
75	79.0587	.0126	1,300.9783	16.4558
80	105.7985	.0095	1,746.6416	16.5091
85	141.5287	.0071	2,343.0450	16.5489
90	189.4698	.0053	3,141.1633	16.5787
95	253.5538	.0039	4,209.2300	16.6009
100	339.3125	.0029	5,638.5416	16.6175
105	454.0770	.0022	7,551.2833	16.6299
110	607.6591	.0016	10,110.9850	16.6392
115	813.1867	.0012	13,536.4450	16.6461
120	1088.2280	.0009	18,120.4667	16.6513

7 PER CENT

n years.	I.	II.	III.	IV.
1	1.0700	.9346	1.0000	.9328
2	1.1449	.8736	2.0700	1.8043
3	1.2250	.8163	3.2142	2.6228
4	1.3108	.7629	4.4400	3.3857
5	1.4026	.7130	5.7514	4.0986
6	1.5007	.6663	7.3529	4.7657
7	1.6058	.6227	8.6542	5.3886
8	1.7182	.5820	10.2600	5.9700
9	1.8385	.5439	11.9786	6.5143
10	1.9671	.5083	13.8159	7.0228
11	2.1049	.4751	15.7843	7.4971
12	2.2522	.4440	17.8886	7.9414
13	2.4098	.4150	20.1400	8.3557
14	2.5785	.3878	22.5500	8.7442
15	2.7590	.3624	25.1286	9.1071
16	2.9522	.3387	27.8886	9.4457
17	3.1588	.3161	30.8400	9.7686
18	3.3800	.2959	34.0000	10.0571
19	3.6165	.2765	37.3786	10.3343
20	3.8697	.2584	40.9528	10.5928
21	4.1406	.2415	44.8657	10.8343
22	4.4304	.2257	49.0057	11.0600
23	4.7405	.2109	53.4343	11.2714
24	5.0724	.1971	55.3200	11.4685
25	5.4275	.1842	63.2500	11.6528
26	5.8075	.1722	68.6786	11.8242
27	6.2140	.1609	74.4857	11.9857
28	6.6490	.1504	80.7000	12.1357
29	7.1144	.1406	87.3346	12.2757
30	7.6124	.1314	94.4628	12.4071
31	8.1452	.1228	102.0742	12.5300
32	8.7154	.1147	110.2700	12.6457
33	9.3255	.1072	118.9500	12.7528
34	9.9783	.1002	128.2618	12.8528
35	10.6768	.0937	138.2400	12.9457
36	11.4241	.0875	148.9157	13.0343
37	12.2239	.0818	160.3414	13.1157
38	13.0795	.0765	172.5642	13.1914
39	13.9950	.0715	185.6428	13.2628
40	14.9747	.0668	199.6386	13.3300
41	16.0230	.0624	214.6143	13.3928
42	17.1446	.0583	230.6371	13.4514
43	18.3448	.0545	247.7828	13.5057
44	19.6290	.0509	266.1428	13.5571
45	21.0030	.0476	285.7571	13.6043
46	22.4332	.0445	306.1886	13.6485
47	24.0463	.0416	329.2328	13.6900
48	25.7888	.0387	354.1257	13.7314
49	27.5306	.0363	379.0086	13.7657
50	29.4577	.0339	406.5386	13.8000
55	41.3162	.0242	575.9458	13.9385
60	57.9482	.0173	813.5458	14.0371
65	81.2755	.0123	1,146.7928	14.1085
70	113.9929	.0088	1,614.1844	14.1585
75	159.8823	.0062	2,141.1757	14.1959
80	224.2440	.0045	2,269.7471	14.2200
85	314.5138	.0032	3,160.6285	14.2385
90	441.1230	.0023	4,478.7682	14.2514
95	618.7000	.0016	6,287.4714	14.2614
100	867.7600	.0011	8,824.2857	14.2685
105	1217.0812	.0008	12,382.2855	14.2728
110	1707.0235	.0006	17,372.5886	14.2757
115	2394.1978	.0004	24,371.7642	14.2785
120	3357.9923	.0003	34,188.5400	14.2800

8 PER CENT

n years.	I.	II.	III.	IV.
1	1.0800	.9259	1.0000	.9250
2	1.1664	.8573	2.0800	1.7825
3	1.2597	.7938	3.2463	2.5762
4	1.3605	.7350	4.5062	3.3112
5	1.4693	.6806	5.8366	3.9912
6	1.5869	.6302	7.3362	4.6212
7	1.7138	.5840	8.9225	5.1987
8	1.8509	.5403	10.6363	5.7450
9	1.9990	.5002	12.4875	6.2462
10	2.1589	.4632	14.4862	6.7087
11	2.3317	.4289	16.6463	7.1375
12	2.5182	.3971	18.9775	7.5350
13	2.7196	.3676	21.4950	7.9037
14	2.9372	.3405	24.2150	8.2425
15	3.1722	.3152	27.1525	8.5587
16	3.4260	.2919	30.3250	8.8513
17	3.7000	.2703	33.7500	9.1200
18	3.9960	.2502	37.4500	9.3712
19	4.3157	.2317	41.4463	9.6025
20	4.6610	.2145	45.7625	9.8175
21	5.0339	.1987	50.4237	10.0150
22	5.4366	.1839	55.4575	10.2000
23	5.8716	.1703	60.8950	10.3700
24	6.3413	.1577	66.7663	10.5275
25	6.8486	.1460	73.1075	10.6737
26	7.3964	.1352	79.9800	10.8087
27	7.9882	.1252	87.3525	10.9337
28	8.6272	.1159	95.3400	11.0500
29	9.3174	.1073	103.9675	11.1575
30	10.0629	.0994	113.2862	11.2562
31	10.8678	.0920	123.3475	11.3487
32	11.7371	.0852	134.2138	11.4337
33	12.6763	.0789	145.9537	11.5125
34	13.6904	.0730	158.6300	11.5862
35	14.7853	.0676	172.3163	11.6537
36	15.9684	.0626	187.1050	11.7162
37	17.2460	.0580	203.0750	11.7737
38	18.6249	.0537	220.3113	11.8275
39	20.1159	.0497	238.9488	11.8775
40	21.7250	.0460	259.0625	11.9237
41	23.4630	.0426	280.7875	11.9662
42	25.3400	.0395	304.2500	12.0050
43	27.3672	.0365	329.5900	12.0425
44	29.5567	.0338	356.9588	12.0762
45	31.9213	.0313	386.5163	12.1075
46	34.4750	.0290	418.4375	12.1362
47	37.2330	.0269	452.9125	12.1625
48	40.2117	.0249	490.1463	12.1875
49	43.4207	.0230	530.2588	12.2112
50	46.9029	.0213	573.7863	12.2325
55	68.9160	.0145	848.9500	12.3175
60	101.2605	.0099	1,253.2563	12.3750
65	148.7849	.0067	1,847.3113	12.4150
70	218.6150	.0046	2,720.1875	12.4412
75	321.2177	.0031	4,002.7213	12.4600
80	471.9761	.0021	5,887.2013	12.4725
85	693.4888	.0014	8,656.1100	12.4812
90	1,018.9649	.0010	12,724.5613	12.4862
95	1,497.1993	.0007	18,702.4913	12.4900
100	2,199.8838	.0005	27,486.0475	12.4925
105	3,232.3656	.0003	40,392.0700	12.4950
110	4,749.4130	.0002	59,355.1625	12.4962
115	6,978.4677	.0001	87,218.3463	12.4975
120	10,253.6792	.0001	128,158.4900	12.4989

10 PER CENT

n years.	I.	II.	III.	IV.
1	1.1000	.9091	1.0000	0.908
2	1.2100	.8264	2.1000	1.735
3	1.3310	.7513	3.3100	2.486
4	1.4641	.6830	4.6410	3.169
5	1.6105	.6209	6.1050	3.790
6	1.7716	.5645	7.7160	4.354
7	1.9487	.5132	9.4870	4.867
8	2.1436	.4665	11.4360	5.334
9	2.3580	.4241	13.5800	5.758
10	2.5938	.3855	15.9380	6.144
11	2.8531	.3505	18.5310	6.494
12	3.1385	.3186	21.3850	6.813
13	3.4523	.2897	24.5230	7.102
14	3.7976	.2633	27.9760	7.366
15	4.1773	.2394	31.7730	7.605
16	4.5950	.2176	35.9500	7.823
17	5.0545	.1978	40.5450	8.021
18	5.5600	.1799	45.6000	8.200
19	6.1160	.1635	51.1600	8.364
20	6.7276	.1486	57.2760	8.513
21	7.4004	.1351	64.0040	8.648
22	8.1404	.1228	71.4040	8.771
23	8.9545	.1117	79.5450	8.882
24	9.8500	.1015	88.5000	8.984
25	10.8349	.0923	98.3490	9.076
26	11.9184	.0839	109.1840	9.160
27	13.1103	.0763	121.1030	9.236
28	14.4213	.0693	134.2130	9.306
29	15.8634	.0630	148.6340	9.369
30	17.4498	.0573	164.4980	9.426
31	19.1948	.0521	181.9480	9.478
32	21.1143	.0474	201.1430	9.525
33	23.2257	.0431	222.2570	9.568
34	25.5483	.0391	245.4830	9.608
35	28.1032	.0356	271.0320	9.643
36	30.9135	.0324	299.1350	9.675
37	34.0049	.0294	330.0490	9.705
38	37.4054	.0273	364.0540	9.726
39	41.1460	.0243	401.4600	9.756
40	45.2605	.0221	442.6050	9.778
41	49.7866	.0201	487.8660	9.798
42	54.7655	.0183	537.6550	9.816
43	60.2420	.0166	592.4200	9.833
44	66.2662	.0151	652.6620	9.848
45	72.8928	.0137	718.9280	9.862
46	80.1822	.0125	791.8220	9.874
47	88.2004	.0113	872.0040	9.886
48	97.0207	.0103	960.2070	9.896
49	106.7228	.0094	1,057.2280	9.905
50	117.3926	.0085	1,163.9260	9.914
55	189.0668	.0053	1,880.6680	9.946
60	304.4944	.0033	3,034.9440	9.966
65	490.3932	.0020	4,893.9320	9.979
70	789.7876	.0013	7,887.8760	9.986
75	1,271.9648	.0008	12,709.6480	9.991
80	2,048.5188	.0005	20,475.1880	9.994
85	3,299.1742	.0003	32,981.7420	9.996
90	5,313.3659	.0002	53,123.6590	9.997
95	8,557.2549	.0001	85,562.5490	9.998
100	13,781.6139	.00007	137,806.1390	9.9992
105	22,195.5102	.00005	221,945.1020	9.9994
110	35,746.1983	.00003	357,451.9830	9.9996
115	57,569.8666	.00002	575,688.6660	9.9997
120	92,717.0213	.00001	927,160.2130	9.9998

TREE MEASUREMENTS AND LOG SCALE TALLY

Locality:........................ *Measured by*:..............(names of crew).............. *Date*:................

Tree No.	Diam. breast-high.	Height of stump.	Dimensions and scale of logs.												Total bd. feet.	Length of top.	Clear length.	Used length.	Merch. length.	Total height.
			1st log (*a*).			2nd log (*b*).			3rd log (*c*).			Etc., etc.								
			Length.*	Diam.†	Bd. feet.	Length.	Diam.	Bd. feet.	Length.	Diam.	Bd. feet.	Length.	Diam.	Bd. feet.						
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* Length in feet and tenths.
† Top diam. in inches and tenths.

Length of crown:.......................
Width of crown:........................

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